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Related to the Silicate Industries

CONTENTS

Original Papers:

Some Observations on the Drying Properties of Clays—Lindsay and Wadleigh 677
Progress Report on Research of Paving Brick from Iowa Shales—Moulton 694
The Calculation of Coal Expenses in Rotary Cement Kilns—Tchernobaieff 702
Principal Refractory Problems of the Malleable Cast Iron Foundry—Schwartz 708
Refractory Requirements in the Gray Iron Foundry—Moldenke 712
The Effect of Variations in Cupola Practice on the Life of the Refractory Blocks—MacKenzie 720
Effects of Composition on the Properties of Sheet Steel Enamels—Wolfram and Harrison 735
Theory of Coal Measure Fire Clays—Lovejoy 756
Comparison of Methods Used in Estimating the Maturing of Terra Cotta—Anderson 762
New Type of Oxy-Acetylene Fusion Furnace, with Notes on the Behavior of Refractories at Cone 40—Gorton and Groves 768
A Machine for Transverse Tests of Clay and Glass Laboratory Specimens—Harrison 774
The Effect of Heat on the Strength of Calcined Kieselguhr-Portland Cement Mixtures—McDowell and Kraner 784

Ceramic Abstracts 297

Book Review 324

The Bulletin:

Editorial 567
Papers and Discussions 571
Activities of the Society 620
Notes and News 627

Advertisers' Index 19

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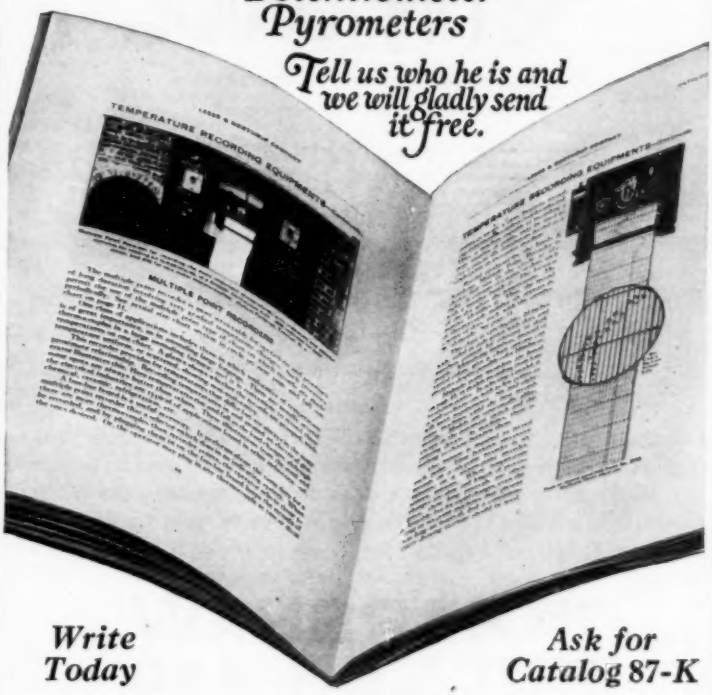

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Vol. 8 **November, 1925** **No. 11**

ORIGINAL PAPERS

SOME OBSERVATIONS ON THE DRYING PROPERTIES OF CLAYS[1]

BY D. C. LINDSAY AND W. H. WADLEIGH

ABSTRACT

This is a preliminary report. After calling attention to some phenomena brought out, the authors discuss the effects of shape, temperature, vapor pressure, humidity and the velocity of air currents as affecting the rate of drying. It is shown that evaporation from the clay sample is directly proportional to surface area exposed per unit weight of the dry clay body and that successful drying is a function of the rate of drying, but a different function for each different type of clay. Data are presented on the relation of transverse breaking strength to residual moisture content for each of several typical clays. The causes of the varying types of drying injuries are pointed out, sample drying schedules are given and a method is suggested whereby the clayworker may without great expense quickly work out for himself in the laboratory the most rapid and safe drying schedules possible for his particular type of material regardless of its character or its source, and to alter his drying practice so as to overcome present difficulties. Brief descriptions are given of the drying cabinet used and of a simple weighing device for automatically indicating, through loss of weight, the amount of moisture already evaporated and the amount of shrinkage the clay has undergone at any moment of observation during the drying process. The information supplied should operate to bring about a reduction in production costs of clay products, and hence of selling prices, to the ultimate consumer. A brief outline of the proposed extension of the investigation is given in the conclusion.

[1] Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce.

I. Introduction

Among the most complex problems encountered by the clayworker is the efficient and successful drying of his ware. No problem of the ceramist has been more neglected, due in part to the large number of factors involved and the complexity of the problem, and in part to succeeding moderately well in the use of natural or uncontrolled means of drying.

The investigation is divided broadly into two parts: first, the determination in the laboratory of the factors controlling drying and the effect of drying treatment upon the physical properties of clay bodies; second, a determination of the drying properties of typical clays from each of the principal deposits of the country.

II. States of Water in Clay

We have used the classification practically as given in the *1921–22 Year Book of the American Ceramic Society.*

1. Water of Plasticity "Water of plasticity" of a clay is all water which can be driven out of the clay in an atmosphere of 4% relative humidity at 110°C.

2. Shrinkage Water "Shrinkage water" is that portion of the water of plasticity which already has been driven off when shrinkage practically ceases.

3. Pore Water "Pore water" is that portion of the water of plasticity still clinging to the surfaces of the grains of the clay substance after shrinkage has practically ceased, but driven out at 110°C in an atmosphere of 4% relative humidity.

4. Hygroscopic Water "Hygroscopic water" is water which remains in the clay after the pore water has been driven off. Thoroughly dried clay will reabsorb a certain amount of water from the atmosphere.

III. Theory of Moisture Removal

The theory of evaporation has been well covered by a number of authors, notably W. K. Lewis[1] and W. H. Carrier.[2] The rate of evaporation of moisture from materials depends upon the following factors:

1. The vapor pressure of the moisture in the material
2. The vapor pressure of the moisture in the air
3. The velocity of the air over the surface of the material
4. The physical properties of the material being dried

[1] W. K. Lewis, "Rate of Evaporation from Solid Materials," *Jour. Ind. Eng. Chem.*, **13,** 429 (1921).

[2] W. H. Carrier, "Theory of Atmospheric Evaporation," *Jour. Ind. Eng. Chem.*, **13,** 423 (1921).

IV. Factors in Rate of Evaporation from Clays

1. Temperature and Vapor Pressure

The temperature of a drying clay body,[1] does not reach the temperature of the surrounding air until it ceases to lose moisture, and this occurs only when the vapor pressure of the clay moisture is equal to that of the air moisture. Figures 1 and 2 show graphically the temperatures observed within two clay bodies during drying, and also the dry and wet bulb temperatures of the surrounding air. The mean rate of moisture loss the first eight hours from the clay of Fig. 1 was slightly greater than for clay of Fig. 2, due possibly to the average relative humidity of the air being slightly lower in the case of the clay of Fig. 1 than it was in that of Fig. 2. However, the observations recorded in Fig. 1 apply to a coarse 50% grog body, while those of Fig. 2 apply to a dense English ball clay. Knowing the wide difference in the porous structure of these two bodies, a difference in drying rates might have been expected even if the relative humidities of the respective surrounding atmospheres were the same.

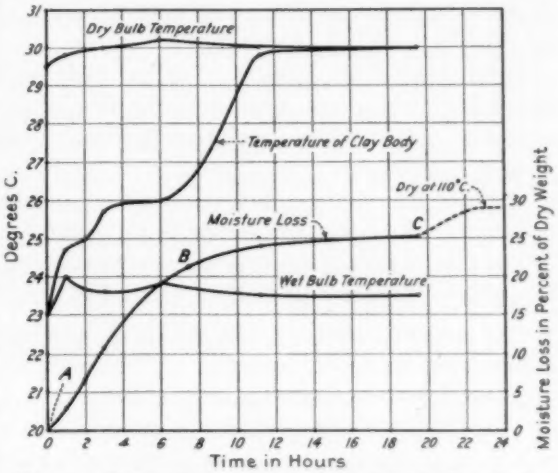

FIG. 1.—Internal temperature of clay during drying. Sagger clay. 50% grog.

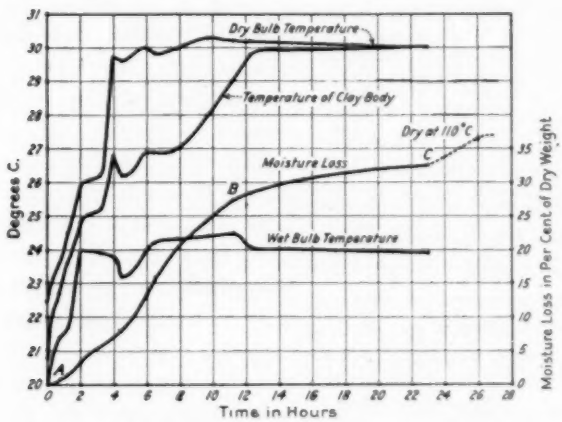

FIG. 2.—Internal temperature of clay during drying. English ball clay. B–5.

[1] In this investigation the temperature was determined by inserting into the plastic clay body the bulb of an ordinary mercury glass thermometer.

Figures 1 and 2 show, not the actual moisture loss in grams but the observed loss of moisture, in per cent of the dry weight of clay, corresponding to the time of drying. These curves of Fig. 1 after the first four hours and of Fig. 2 are typical of the drying of clays under conditions of constant temperature and humidity of the surrounding air. For convenience in discussion the moisture loss curves may each be divided arbitrarily into two sections: *A–B* and *B–C*.

From *A* to *B* the moisture loss proceeds, roughly, at a uniform rate. Beyond *B* during the stage *B–C* the rate of evaporation decreases continuously, approaching a state where no further moisture loss occurs at that temperature and humidity. Simultaneously with this decrease in rate of evaporation the temperature of the material rises, rapidly approaching the dry bulb temperature of the air.

The rate of evaporation during the time *A–B* is approximately described by the equation for evaporation from a free liquid surface:

$$dw/dt = (e' - e)C$$

where dw/dt = rate of evaporation
e' = vapor pressure in the material
e = vapor pressure in the air
C = a constant for a particular clay

The principal cause of deviation from this rate equation seems to be shrinkage; the progressive reduction of evaporating surface together with the decreasing moisture content is doubtless responsible for the slow decrease in the rate of evaporation shown near point *B*.

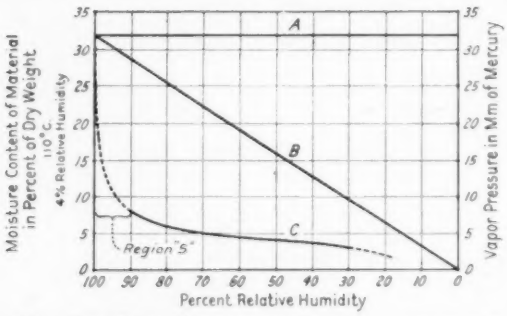

FIG. 3.—Theoretical *vs.* actual vapor pressure in clay. Constant temperature of material = 30°C. Key: *A*—Vapor pressure maximum at 30°C. (Clay saturated.) *B*—Vapor pressure in material corresponding to moisture content. *C*—Normal moisture content of material corresponding to relative humidity.

The rate of evaporation during the time from *B* to *C* does not follow the laws applying to time *A–B*, and is complicated by numerous factors. The vapor pressure of the water still remaining within the material does not even approximate the vapor pressure of free water at the temperature of the material. The water remaining is not free water, but adheres to the walls of the pores and capillaries. Its vapor pressure is reduced probably by capillary restriction, by a natural

affinity between the water and the material, and possibly by a colloidal relation with which we are not familiar.

This reduction in vapor pressure below that corresponding to the temperature of the material is well illustrated in Fig. 3. It is a familiar fact that any hygroscopic material placed in an atmosphere of fixed humidity will come to an equilibrium weight in that atmosphere, gaining or losing moisture according as its initial vapor pressure is less or greater than that of the atmosphere. Curve C, Fig. 3, represents the recorded equilibrium conditions for a clay[1] during the process of drying at various humidities and a constant air temperature. Line A, Fig. 3, is the maximum vapor pressure which could exist in the clay at the constant temperature of 30°C. Line B, Fig. 3, indicates the vapor pressure in the air and also the actual vapor pressure in the clay at the various relative humidities, since to be in equilibrium the effective vapor pressure of the evaporating liquid in the clay must be equal to the vapor pressure in the atmosphere. We may note also that in this figure the vertical distance between lines A and B, for any given humidity, represents the difference between the pressure of saturated water vapor, corresponding to the temperature of the clay, and that vapor pressure which actually exists in the clay.

These observations of equilibrium conditions were made in a drier in which it was not possible to maintain a satisfactorily constant relative humidity above 90%, so that between 90% and 100% relative humidity, curve C is simply approximated. We know, however, that at 100% relative humidity there would be no evaporation from the clay and that the moisture equilibrium points between 90% and 100% must lie along some such extension of the curve as shown in Fig. 3 and designated "region S." We observe also from Figs. 1 and 2 that down to a residual moisture content of about 8% of the dry clay weight evaporation proceeds at a nearly uniform rate, which means that the moisture is evaporating essentially as from a free liquid, and therefore, that its vapor pressure is the same, or only slightly lower, than that corresponding to the temperature of the clay. In order to satisfy this condition, the ordinate of curve C, Fig. 3, must have an initial value equal to that of the maximum vapor pressure line.

2. Velocity of Air over Material

The air serves: first, as a conveyor of heat to the clay body; second, to sweep away the saturated vapor from the drying surface. Up to a certain critical velocity the rate of evaporation from a free liquid surface main-

[1] In the case of this particular clay, it so happens that in a saturated atmosphere at 30°C its moisture content expressed as a percentage of dry weight of clay is just equal numerically to the vapor pressure expressed in mm. of mercury, and hence the moisture content and pressure have been plotted to the same scale. At other temperatures or with a different type of clay, it would in general be necessary to plot these to different scales.

tained at a constant temperature increases in approximately direct proportion to the velocity of the air over the surface.[1] For such a free liquid surface this critical velocity is very large, but for a drying clay body it is probably never more than about three meters, or ten feet, per second.

On the other hand while as applied to the drying of clays, the law doubtless holds initially, the "critical" air velocity must here be defined as that velocity at which the air current removes moisture from the clay surface at a rate equal to the rate of moisture diffusion from the interior of the wet clay body, and for some clays is probably somewhat less than the above mentioned value. Beyond this critical value any increase in air velocity has little effect upon the rate of evaporation. While no actual velocity measurements have been made during this investigation to determine this limiting rate as applied to clay, Fig. 4, based upon observations of others, indicates the character of the effect.[1]

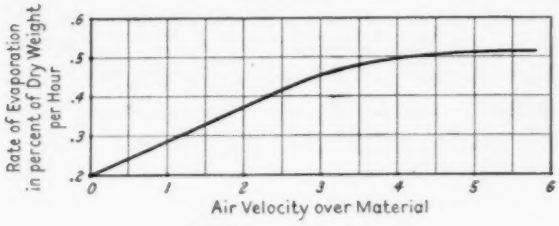

FIG. 4.—Relation of evaporation to air—velocity.

TABLE I

COMPARISON OF DRYING RATES OF SEVERAL CLAYS HAVING DIFFERENT POROSITIES

Specimen 1″ x 1″ x 7″	Type of clay	Dry bulb temp. of air, °C	Relative humidity, per cent	Rate moist. loss, per cent per hour	Av. poros. per cent, dry volume
K–2	North Carolina kaolin	30	85	0.8	41.5
B–2	English ball clay	29	85	0.3	38.5
B–3	English ball clay (same as B–2)	30	85	0.28	39.5
FE-4	Whiteware body	31	86	0.8	32.7
P–2	Whiteware body	32	86	0.5	30.5

Effective velocity of air over specimens the same in all cases.

3. Physical Properties

Other factors affecting the rate of evaporation from clays are (*a*) internal structure (porosity) and (*b*) form (surface exposed relative to mass).

(*a*) Porosity

It is generally considered that the ease with which a clay may be dried depends upon the porosity of the molded material. Undoubtedly it is true that a *given clay* may be made to dry more rapidly by increasing the porosity through the addition of grog or other coarse material. In comparing the drying rates of *different*

[1] W. H. Carrier, Jr., "The Temperature of Evaporation," *Jour. Amer. Soc. Heat. and Vent. Eng.*, **24**, 25 (1918). Also Coffey and Horne, "Theory of Cooling Powers Compared with Results in Practice," *Jour. Amer. Soc. Refrig. Eng.*, **2**, 25, May (1916).

clays, however, it has been found that the measured porosity of the dried specimen may not be relied upon solely as a comparative indication of the rate of drying. Table I is a comparison of the drying rates of several clays under practically identical air conditions. Such a comparison would lead one to believe that the rate of evaporation from clays, other conditions being constant, depends more upon the *type* of porous structure, than upon the *amount* of *pore* space.

(*b*) **Form**

It is a common observation that massive clay pieces dry more slowly than light ware, when exposed to like conditions. As a basis for comparing the drying weights of different masses and forms of the same clay, we have chosen as a term to express this difference—the area exposed per unit mass of clay. For instance, a cubic centimeter of clay which weighs one gram, having dimensions 1 x 1 x 1 cm. and having five faces exposed to the air, has an exposed area of 5 sq. cm. per gram. A like weight of clay, having dimensions 2 x 2 x 0.25 cm., standing on edge, has an exposed area of 9.5 sq. cm. per gram.

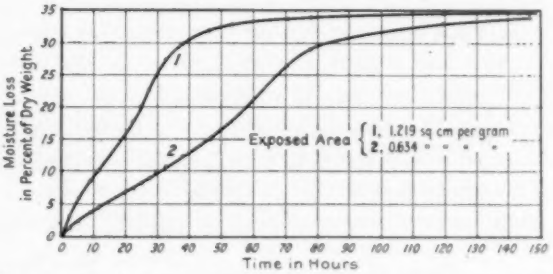

FIG. 5.—Variation in drying rate relative to area exposed per unit mass.

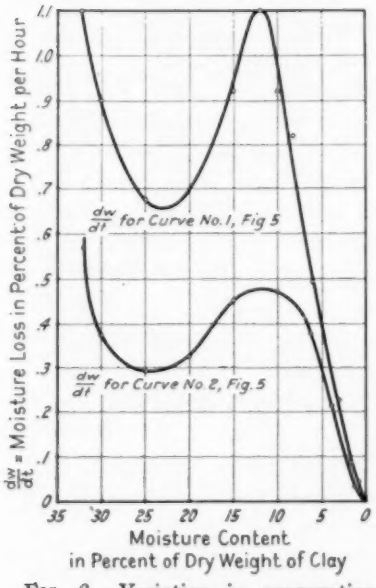
dw/dt = Moisture Loss in Percent of Dry Weight per Hour
dw/dt for Curve No. 1, Fig 5
dw/dt for Curve No. 2, Fig. 5
Moisture Content
in Percent of Dry Weight of Clay

FIG. 6.—Variation in evaporation rate with water content and area per unit mass.

The results of several laboratory tests to determine the effect of variation in surface exposed upon the rate of drying have shown that the instantaneous rate of moisture loss from identical clays, other conditions being constant, varies approximately in direct proportion to the surface exposed per unit dry weight of the clay.

Figure 5 illustrates the results obtained in drying two specimens of English ball clay under identical conditions. Curve 1, Fig. 5, shows the loss of moisture, in per cent of dry weight, plotted against time and is for a specimen

approximately cubical in form, having 1.22 sq. cm. per gram of clay exposed to the air. Curve 2, Fig. 5, is the loss curve for a like specimen, which has 0.634 sq. cm. per gram of clay exposed to the air, slightly more than one-half that of No. 1. It will be observed that at all identical stages of moisture loss, Curve 1 rises at about twice the rate of Curve 2. This is shown in Fig. 6 where the instantaneous rates, dw/dt, *i. e.*, the tangents of the curves in Fig. 5 are plotted against the per cent of moisture remaining in the corresponding specimens.

If, now, the rate of evaporation varies directly with area exposed per unit weight, we may state that, other conditions being identical, the rate of evaporation, in per cent of clay weight, varies as the area exposed to the air per unit weight of clay, and is the same regardless of size or shape.[1]

This relation may be expressed as $r_1/a_1 = r_2/a_2$.

Table II gives the values of r/a from data plotted in curves of Fig. 6. Comparison of the rate-area relations shows r/a to be essentially constant. This relation is useful in estimating the drying rates of commercial ware from observations made on laboratory specimens.

TABLE II

COMPARING THE RATE OF EVAPORATION IN PER CENT (RELATIVE TO DRY WEIGHT) Per Hour, per Square Centimeter Area Exposed, per Gram (Dry Weight)

Moisture content of specimen in per cent dry weight (w)	Area exposed, sq. cm. per gm. (a_1)	Area exposed, sq. cm. per gm. (a_2)	Moisture loss, per cent per hour (r_1)	Moisture loss, per cent per hour (r_2)	$\frac{r_1}{a_1}$	$\frac{r_2}{a_2}$
30	1.2193	0.6342	0.66	0.34	0.540	0.537
25	1.2193	.6342	.67	.30	.550	.475
20	1.2193	.6342	.72	.33	.590	.521
15	1.2193	.6342	.97	.47	.795	.740
10	1.2193	.6342	.98	.49	.803	.773
5	1.2193	.6342	.34	.16	.278	.252

4. Summary of Factors Affecting Evaporation

Other factors remaining constant: Rate of evaporation increases with rise in temperature of air, due to increase of effective vapor pressure in the material.

Rate of evaporation decreases with rise in wet bulb temperature of the air, due to the corresponding rise in relative humidity and corresponding reduction in the difference between the vapor pressure in the material and the vapor pressure in the air.

Rate of evaporation decreases, after shrinkage water has been removed, with decrease in moisture content, due to demonstrated decrease in effective vapor pressure in the material. (See Fig. 3.)

Rate of evaporation is increased by increasing the exposed surface area per unit weight of body.

[1] Of course, in complicated shapes conditions may be introduced which would prevent the body from being exposed to uniform conditions of air over its entire surface.

V. Effect of Rate of Evaporation upon Clay

Having made the foregoing analysis of the factors affecting the rate of evaporation from clays, the effect of rate of evaporation upon clay bodies should be examined.

1. Classification of Clays

Lovejoy has classified clays,[1] with respect to their drying qualities, as follows:

(*a*) Clays that may be dried in a few hours, starting with an initial high temperature and rapid drying conditions.

(*b*) Clays that may be dried in 24 hours or less, starting at an initial low temperature in saturated atmosphere.

(*c*) Clays that can be dried in 24 hours to 72 hours, under conditions of (*b*).

(*d*) Clays that require over 72 hours under conditions of (*b*).

(*e*) Clays that must be slowly heated up in a saturated, stagnant atmosphere before advancing into a moving drying atmosphere.

(*f*) Clays that cannot be safely subjected to conditions under (*b*) or (*e*), but must be dried slowly, starting under drying conditions (*i. e.*, in an unsaturated atmosphere).

(*g*) Clays that cannot be dried under any conditions.

For the purpose of this discussion, we accept this classification, pending the completion of our classification of clays according to their drying properties.

2. Success in Drying Depends upon Rate

In the drying of any clay body, the rate of evaporation from the surface relative to its replacement by diffusion from within, is the all-important factor. According to the foregoing classification, there are clays which may be subjected to an extremely high rate of moisture removal without injury to the mass, while at the other extreme there are clays which can not be dried without cracking or other injury under any circumstances.

3. Types of Drying Injuries

The types of drying injuries of most common occurrence in clay bodies are: warping, breaking, large cracks, checking (fine cracks distributed uniformly over the surface), cracking along laminations, strains.

(*a*) **Warping and Cracking**

Warping is caused by a non-uniform rate of drying between opposite surfaces of the clay body. It is simply the adjustment of the semi-plastic mass to an uneven rate of shrinkage throughout the body. Warpage has been observed to occur in laboratory briquet specimens under the following conditions: Specimens placed on pine boards and subjected to a highly humid atmosphere, warped up from the board in an arch, leaving two ends in contact. In this case, the board was absorbing water from the under

[1] Ellis Lovejoy, "Drying Clay Wares," T. A. Randall & Co. (1916).

side of the specimen at a greater rate than evaporation occurred from the exposed surfaces; a difference in shrinkage between the two sides was the natural consequence. Again, warpage has been observed to occur in the direction opposite to that just described, when the exposed surfaces are subjected to a current of air which carries the moisture away at a rate greater than the surface replacement by diffusion. Warpage occurs most frequently in light wares. The same causes bring about cracking in heavy ware when the mass of the clay is too great to be shifted or lifted by the strains resulting from uneven shrinkage.

(*b*) **Checking** Checking in ware is caused, not by an uneven rate of moisture removal from the different surfaces of the ware, but by excessive rate of evaporation from the entire surface. When evaporation from the surface occurs at a rate greater than that at which moisture is being replaced by diffusion from within, an excessive rate of surface shrinkage occurs. The result of this is a compression of the inner core of the body. The strength of the shrinking surface layer is not sufficient to withstand this strain and so breaks along rather uniform strain lines, much like crazing in glazes. These cracks, fine at first, often penetrate far into the body before drying is completed.

(*c*) **Laminations** Laminations in a ware are a common cause of drying cracks. The probable initial cause of laminations rests in defective molding of the ware, and is often first seen in the dried, or unfired, piece. A lamination occurs as a fold or dividing space within the body of the clay. Transfer of moisture across the interrupted channels of such a space is difficult. Water tends to collect in this space, there to build up later a vapor pressure with the rise of drying temperature. Most often it happens that such a pressure forces the water out along the lamination plane and, in so doing, ruptures the ware.

(*d*) **Strains** Strain in dried clay ware is a less tangible term than any of the other defects mentioned. We are not sure that strain exists in dried ware that is apparently uninjured. We can only judge by the comparative dry strength of pieces alike as to porosity and other properties, and by those pieces which fail in the early firing stages. It is certain that dry clay has little elasticity and that strains of any considerable magnitude, set up during the drying process, must result in warping or cracking. Cracking that has thus occurred may be made up of very minute lines, not readily detected by the eye, but which appreciably reduce the strength and cause almost certain failure in the kiln.

(*e*) **Sticking** An additional injury frequently found is the tendency of the wet specimen to stick to the drying pallet. As shrinkage proceeds, if the body does not readily slide on the pallet, the resulting strain causes the body to crack across the contact surface.

VI. Drying Schedules and Physical Properties of Clays

1. Selection of Clays for Test

A portion of this investigation has been to select clays for which various safe drying schedules were to be found and the physical properties of the specimens dried under different conditions compared. The selection of clays for this part of the investigation was made for the purpose of finding what physical properties are affected in drying, rather than for a study of the particular clay. The clays thus far treated have been:

(*a*) Specimens composed entirely of English ball clay
(*b*) Specimens composed entirely of North Carolina kaolin
(*c*) Several whiteware body compositions
(*d*) Several clays used in the manufacture of common brick
(*e*) Several shales

2. Maximum Rate vs. Efficiency

The first problem in drying is to find a safe drying schedule. In plant practice, other factors may enter in the most effective rate of drying. The maximum safe rate of drying is not necessarily the rate of maximum efficiency, due to the additional total heat required to evaporate water at increasingly high temperatures.

Figure 7 is an example of a safe schedule found for a semi-porcelain body made into standard briquets (1″ x 1″ x 7″). Conditions of temperature, relative humidity and air velocity were controlled and observed throughout the process. The graphical record of moisture loss and air conditions often shows where the drying may be safely hastened and how the schedule might be shortened, as is well illustrated in Fig. 7.

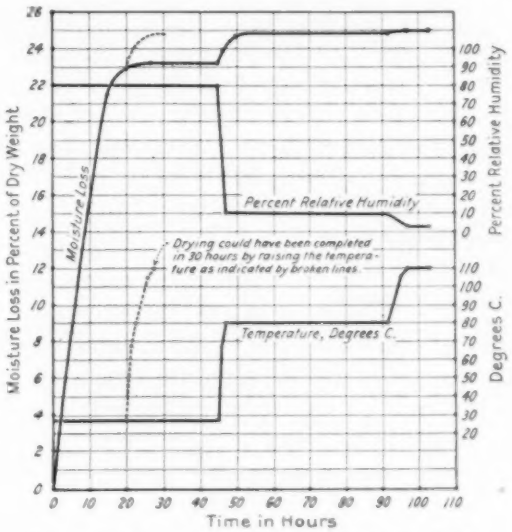
Moisture Loss in Percent of Dry Weight
Percent Relative Humidity
Degrees C.
Time in Hours
Moisture Loss
Percent Relative Humidity
Drying could have been completed in 30 hours by raising the temperature as indicated by broken lines.
Temperature, Degrees C.

FIG. 7.—Example of drying schedule for semi-porcelain body. P–3–0.

3. Observations and Factors in Establishing Drying Schedules

Figure 8 is a schedule similar to Fig. 7, except that it is the drying record of an extremely plastic clay body, having a large shrinkage factor. In this case, the progressive linear shrinkage was observed simultaneously with the weight loss.

The observation of the rate of shrinkage and the point at which shrinkage is completed, is extremely important in establishing drying schedules. It will be observed that, in the first stages of drying, shrinkage progresses by an approximately uniform rate along a curve similar in form to the Moisture Loss Curve. At a definite point the rate of shrinkage decreases abruptly and approaches a condition where shrinkage is completed. Up to, and especially immediately preceding, this point where shrinkage ceases the clay body being dried is in a critical state and can easily be injured by an excessive rate of moisture removal. Beyond the point where shrinkage is practically completed, drying may be safely hastened to the end by increasing, in proper steps, the temperature and velocity of the air and by reducing the humidity.

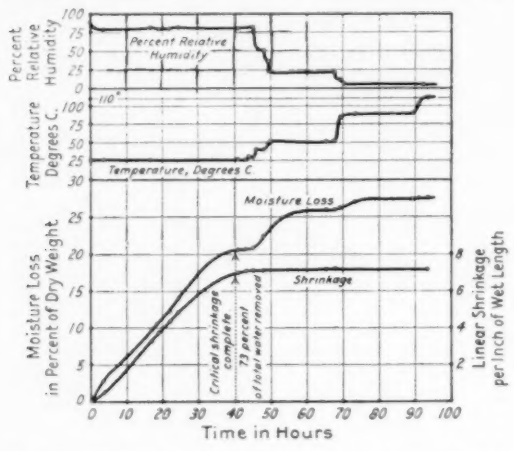
Percent Relative Humidity
Temperature Degrees C.
Temperature, Degrees C.
Moisture Loss
Shrinkage
Moisture Loss in Percent of Dry Weight
Linear Shrinkage per Inch of Wet Length
Critical shrinkage complete. 73 percent of total water removed
Time in Hours

FIG. 8.—Example of drying and shrinkage schedule plastic clay. M–1.

4. Strength of Specimens Dried at Different Rates

Although we have some evidence that the strength of apparently uninjured dry ware is affected by the rate at which drying has taken place at the various stages, we are not yet prepared to present conclusive data. The modulus of rupture of raw clay specimens, molded with extreme care in the attempt to obtain uniformity of structure, at the best varies over a rather wide range between like specimens. If dry porosity be taken as an index of structure, the variation in strength does not seem to be entirely justified by the slight variation in porosity.

TABLE III

COMPARISON OF THE MODULUS OF RUPTURE WITH POROSITY

English ball clay B-3-W specimen no.	Modulus of rupture, lbs. per sq. in.	Porosity in per cent of dry volume
1	417	40.22
2	314	41.10
3	399	40.69
4	361	41.00
5	346	41.99
6	428	40.39

Table III shows the strength and corresponding porosity of a set of English ball clay specimens dried under identical conditions.

5. Variation in Dry Strength According to Residual Moisture Content

The strength of dried specimens, we found, has a decided and consistent variation according to the residual moisture of the specimens. The curves presented in Figs. 9, 10 and 11 show this variation for three different bodies. The curve in Fig. 9 is for a standard semi-porcelain body; Fig. 10 is for a plastic Texas clay used in common brick, and Fig. 11 represents an Iowa shale. The amount of moisture remaining in the body is stated in per cent of weight of the body when dried to a constant weight in air at 110°C and about 4% relative humidity.

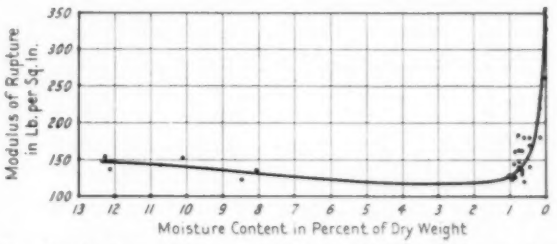

FIG. 9.—Relation between moisture content and modulus of rupture. Semi-porcelain body. P–3–0.

These samples were broken, then immediately weighed and weighed again when dried under the above conditions, in order to find the per cent moisture remaining at the time of breaking. The curves pass through the mean of the moduli observed. The decided increase in strength, with the removal of the last per cent of water, is notable in each case, particularly that of the semi-porcelain body.

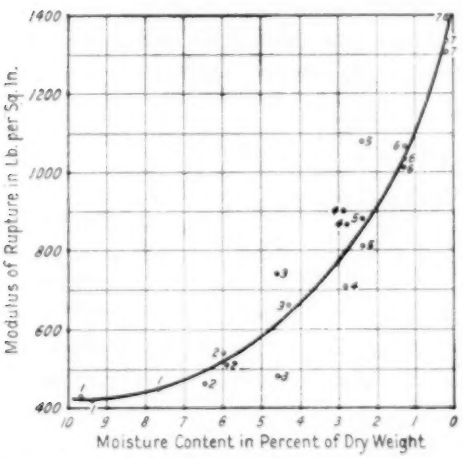

FIG. 10.—Relation between moisture content and modulus of rupture. High plastic clay. M–2.

The moisture regain of these three bodies, during several weeks at average room temperature and humidity, was found to be:

Semi-porcelain body	0.7%
Shale	0.7%
Texas clay	2.5%

A decrease in strength corresponding to moisture regain, occurred in shale and clay.[1]

[1] We found a marked increase in strength with aging in the dry state in English ball clay specimens, some semi-porcelain bodies and North Carolina kaolin specimens. This seems to be independent of the change in moisture content. We are not prepared to make a definite report upon this peculiarity.

VII. Conclusion

This is intended to be only a preliminary report of the drying investigation to date. We have emphasized the factors which govern drying and pointed out the injuries that may occur to clay products when these factors are disregarded.

We believe safe drying schedules used in practice may be approximated in the laboratory from samples of the body and a description of the ware manufactured. By the same laboratory methods and a history of the treatment to which the ware has been subjected it is possible, in most cases, to locate the cause of drying injuries.

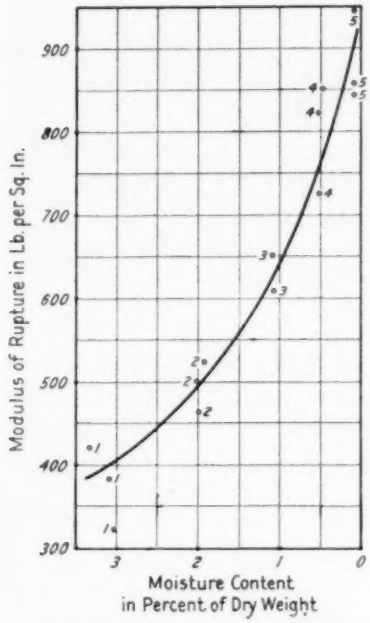

FIG. 11.—Relation between moisture content and modulus of rupture. Iowa shale. A–1.

This survey will be of use in selecting drying equipment, and in altering drying practice to overcome present difficulties.

The methods of controlling drying conditions in the plant are a part of the investigation as yet untouched. Perhaps this portion of the work should rest with the manufacturers themselves and with concerns engaged in the design and manufacture of driers. There are already several forms of equipment admirably suited to cope with plant drying problems.

Appendix.

Processing Cabinet For the purpose of controlling temperature, humidity and air circulation in drying, a Carrier Ejector Processing Cabinet was used. This has proven to be a convenient and useful piece of laboratory equipment. Figure 12 is a longitudinal cross-section of the cabinet showing the arrangement of specimens and indicating the air circulation.

Humidity Control The relative humidity within the cabinet is controlled by means of an adjustable hygrostat mounted on the outer casing and having, protruding into the cabinet, a silk member sensitive to variations in relative humidity. The hygrostat acts upon an atomizing water spray nozzle located near the fan's intake. The instrument will maintain the relative humidity within 3% of the value for which it is set.

Temperature Control The heating of the air is done by electrical elements located at the fan intake. Temperature is controlled by means of a thermostat adjustable from the exterior of the cabinet. The thermostat operates within an accuracy of about 1°C above or below the mean.

Velocity The velocity of the air over the material may be adjusted as desired by the use of a damper in the air supply duct or by varying the speed of the fan motor.

Moisture Loss and Shrinkage Observations By means of a balance, located on top of the cabinet, and the specimen pan suspended by an extension link within the cabinet (see Fig. 12), frequent observations of the moisture loss can be made, without interruption of the drying conditions. It was from such observations that the above mentioned moisture loss curves were plotted.

Shown also in Fig. 12 is a continuous shrinkage micrometer devised for this work. This is comprised of two horizontally adjustable heads mounted upon a slotted bedplate. Upon each head is mounted an Ames dial micrometer (1/100 mm. div.). The specimen is placed upon a pallet as shown and observations of shrinkage made simultaneously with the observations of weight loss from a like specimen upon the balance pan. Such comparative observations of moisture loss and shrinkage are important, as previously pointed out.

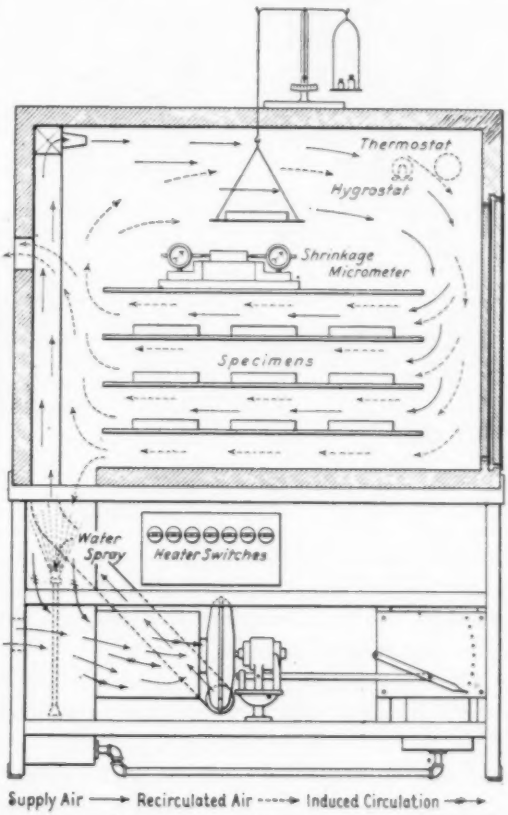

FIG. 12.—The Carrier Ejector Processing Cabinet.

Optical Flexure Balance One of the most tedious tasks in studying the physical properties of clays is the numerous weighing operations, particularly in the determination

of porosity. This work was greatly facilitated by the development and use of an optical flexure balance as hereinafter described.

Figure 13 is a diagram of the apparatus used. The principle is simply that of the optical lever in which small deflections of a flexible steel member are magnified through the use of a mirror, a distant scale and a telescope. Object A is the balance. a is the flexible steel strip (a hack saw blade is suitable) clamped in the split block f. The length of the flexible strip, and therefore its deflection per unit weight, is adjustable by loosening the clamp and sliding it backward or forward. b, the specimen pan, is suspended by links as shown. c is a small mirror pivoted on either side on top of block f, and capable of turning as the arm is deflected. Rod d, attached to the back of the mirror c, rests upon the flexible arm

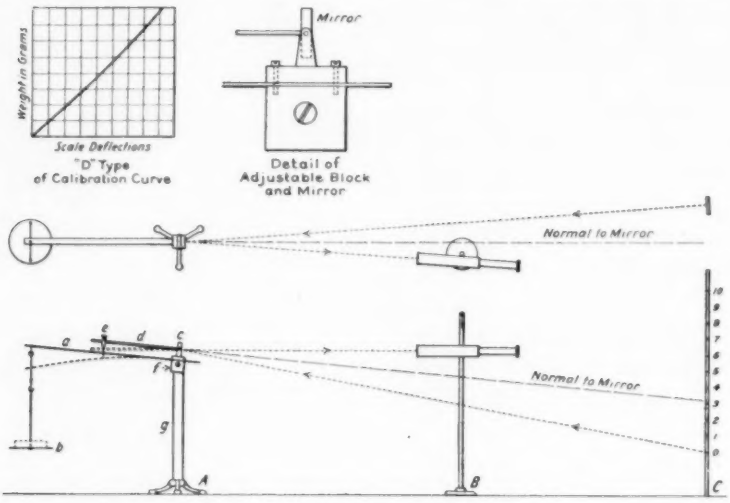

FIG. 13.—Optical flexure balance.

through the adjustable knife edge e. B is an ordinary laboratory telescope. C is a scale adjusted on an angle, as shown, and at a distance governed by the focal length of the telescope and by the desirable amount of deflection magnification.

The following members of balance A are adjustable for calibration purposes: Flexible arm a, adjustable as to length; knife edge e, adjustable along rod d, to vary deflection of mirror c; block f, adjustable about an axis perpendicular to pedestal g, to adjust zero deflection from scale.

Calibration

Calibration is accomplished by placing successive known weights upon the pan and plotting a curve—weight *vs.* scale deflection. The curve will not be a straight line following Hooke's Law, but will be slightly concave as shown in D (Fig. 13). This is due to the fact that flexible arm a and rod d turn about different centers.

Sensitivity As used, adjustment was made to cause a deflection of approximately one-half centimeter per gram. The scale used was divided into millimeters. With this scale it was possible to read accurately to $^1/_5$ gram. Using the cross hair in the telescope $^1/_{10}$ gram could be estimated. Numerous checks of weights with a precision balance showed a maximum error of $^1/_{10}$ gram. In 50 gram specimens (which are convenient), this amounts to an accuracy within $^1/_5$ of 1%.

The balance is found to be particularly convenient and useful in weighing materials suspended in oil or other liquids. It is only necessary to suspend the pan in the liquid, note the new zero reading, then proceed in the usual manner to place specimens on the pan as immersed in the liquid.

PROGRESS REPORT ON RESEARCH OF PAVING BRICK FROM IOWA SHALES[1]

By D. A. Moulton

ABSTRACT

Test on full size pavers made from 11 shales showed that five would make an excellent paving material and others had possibilities of making a block that would give service. Various processes were tried as soft-mud, roller expression machine, dry-press, and a new belt machine, also additions of magnesium and colloidal materials. The soft-mud, roller expression machine gave equal if not better results than the stiff-mud process, and the other processes required higher temperatures to get a suitable block for test. Magnesium reduced the rattler test from 27% to 22% and changed the color to a buff similar to that of fire clay. The colloidal materials made the shale more refractory and hence the brick were too soft for the rattler test.[2]

Use	General average loss	Maximum permissible loss
Heavy traffic	22%	24%
Medium traffic	24%	26%
Light traffic	26%	28%

Paving brick have been made for some time in Des Moines, Ia., and there have been attempts to make paving block in other parts of the state. Eleven shales were selected in the various clay-working districts of Iowa.

1. Standard Brick Co., Oskaloosa, Ia.
2. Lehigh Sewer Pipe Co., Lehigh, Ia.
3. Flint Paving Brick Co., Des Moines, Ia.
4. Van Meter Tile Co., Van Meter, Ia.
5. Kalo Brick & Tile Co., Fort Dodge, Ia.
6. Boone Paving Brick & Tile Co., Boone, Ia.
7. Morey Clay Products Co., Ottumwa, Ia.
8. What Cheer Clay Co., What Cheer, Ia.
9. Redfield Brick & Tile Co., Redfield, Ia.
10. Davenport Brick & Tile Co., Davenport, Ia.
11. Adel Clay Products Co., Adel, Ia.

Description of Samples

Samples 1, 7 and 10 are dark colored shales containing organic materials and other carbonaceous materials which require some time to oxidize completely in the firing of a block as thick as paving brick. All fire to a good red color vitrifying in a safe range of temperatures.

Samples 2, 3, 5, 6, 8, 9 and 11 are red to reddish brown with streaks of blue running through the shales in some samples. All are quite free from

[1] Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, February, 1925. (Heavy Clay Products Division.)

[2] The American Society for Testing Materials has not given any definite specifications in regard to results required of the rattler test, leaving this to be decided by local conditions. However, they give the following for maximum permissible loss and the general average loss in this test.

excess of carbonaceous materials, being easily oxidized and having a good range of vitrification.

Sample 4 is a very soft plastic shale firing to an excellent red color but developed a brittle brick which did not stand the rattler test.

Process of Manufacture

The ground shales were pugged both by hand and by wet pan and wedged by use of large wooden mallet, into rectangular pieces 9 x 9 x 24 inches to fit in an iron receiver on a plunger machine which is operated by hand; the crank is connected by gears to the plunger thus increasing the power. This plunger forced the clay out of a die $4^{7}/_{16}$ x $3^{5}/_{16}$ inches into a column of clay which was cut into $8^{3}/_{4}$-inch lengths, thus making an end cut brick. This preparation was designed to make brick of similar structure as is done in commercial plants and was accomplished to a surprising degree as shown by the rattler loss on a brick made in plant and those made of same clay in the laboratory running very close together. There was no

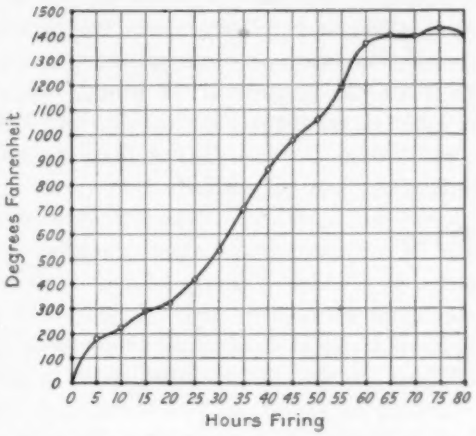

FIG. 1.—No. 1 firing. Paving brick. Cone 04 down. 77 hours to 1480°F. Sample numbers 1, 4, 9, 10. Lower temperature clays.

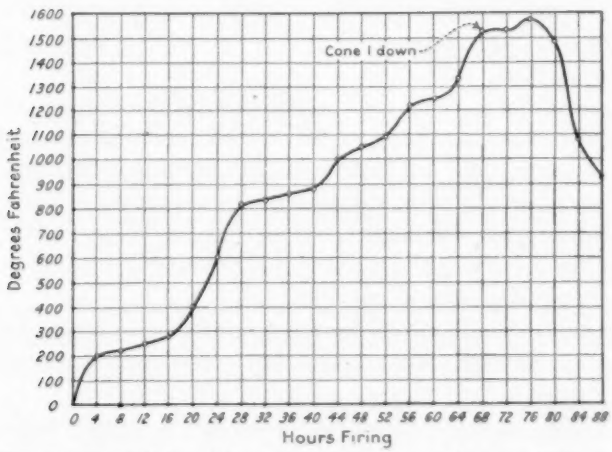

FIG. 2.—No. 2 firing. Paving brick. Cone 1 down. 76 hours to 1570°F. Samples 2, 3, 5, 6, 7, 8.

difficulty found in drying these brick as it was done slowly in the room temperature of the laboratory.

Firing These dried brick were fired in an oil fired round down draft kiln, 4 feet in diameter. The time temperature schedule of these firings as indicated on Fig. 1 brought cone 04 down in 77 hours and the second fire cone 1 down in 88 hours' time. The brick were quartered for trial pieces and these were pulled often to check the progress of the firing. They were particularly accurate and reliable in regard to vitrification, but owing to the fact that they were smaller than the brick did not give accurate information in regard to the oxidation of all of the various shales.

Testing These fired brick were then tested in the standard rattler machine consisting of a drum having 14 sides, into which a charge of shot is placed, 75 pounds of large spherical steel shot and 225 pounds of small shot and the ten block to be tested. It is revolved 1800 revolutions per hour and the loss by weight obtained. The per cent loss is calculated on the original weight of brick.

Results

1. Difficulty in oxidizing this clay prevented a successful test at the present time. It is quite possible to make a paver from this shale as they have been made and used to good advantage; however, to meet the present severe test required of paving brick it would be at quite a disadvantage as compared to other available shales in the state.

2. This material made a paver which had a rattler loss of 24.7% and 24.2% which would be available for medium traffic calling for a loss between 24% and 26%. It would no doubt make a tougher block if there was added more siliceous material as it is very plastic and the block is inclined to be brittle.

3. This material is being used in the successful manufacture of paving block and was used to compare process of manufacture in laboratory with that of commercial conditions. The highest loss obtained in laboratory brick was 23.18% when the absorption was only 0.77%. Other tests where the absorption was higher ran around 19.7% loss. This was evidence that the laboratory method was approaching very close to actual conditions in plant process of manufacture.

4. This shale developed the best red color of all samples and vitrified to a very dense, though glassy matrix, but was entirely too brittle to withstand the rattler test.

5. This shale fired to a dark brown color on the surface having a lighter interior and developed one of the toughest block among the shales tested. The lowest was 18.7% loss and the average for three tests was 20.1%

with an absorption of 7% indicating that with a little harder firing this shale may even show a lower rattler loss. It is evident that this shale would give no trouble in producing pavers the equal of any from competing plants both in and out of the state.

6. This shale has been made into pavers which have been used and given good service in the roads but is just on the edge of the usual requirements of the rattler test. It is quite sandy and the block with lower absorption gave the highest rattler loss namely, 5.1% absorption with 27.9% rattler loss, while the block of 7.2% absorption had a rattler loss of 21.7%.

This block was noticeably regular in the wear during the rattler test and none of the brick broke into halves or chipped off but wore uniformly, indicating that it may be improved by having a better bond in the raw material.

7. This dark shale contains carbon and organic materials which require more attention than was given to it in the first firing of this shale. Due to the fact that this brick had a large blue core in the center, the tests are higher than one would expect it to be when this core is properly oxidized. The rattler loss was 24.7% and absorption 4.8% which is high for medium traffic average but under the maximum permissible loss. This material has given good service in local pavements.

8. This is a light gray shale easily worked on the stiff-mud process, having some organic and carbonaceous material in it which gave little or no trouble in the oxidizing period of the firing. The average of two tests on this shale gave a rattler loss of 20.3% with an absorption of 5.28%. This rattler loss is below general average loss for heavy traffic and no doubt this shale will successfully produce pavers with a margin of safety in regard to the firing of same as it is a very tough material.

9. This brown shale is very plastic and has little impurities which give trouble in the firing, especially in the oxidation period. It fires to a good red color at cone 1, 1850°F, which appears to be a little too low a temperature.

The rattler loss was 23.8% and 24.5% with average of 24.1% and absorption of 4.7%. This rattler loss places brick better than that required for average light traffic. When fired to 1950°F it had a rattler loss of 18.8% with absorption of 2.48% which indicates that this material with proper firing will give an excellent paving block. It would have to be tied rather securely in the setting as it has considerable shrinkage (15% linear) which may cause it to roll or pull when settling or vitrifying.

10. This blue shale was difficult to oxidize and was not successfully oxidized in our firings, hence the presence of a bad blue core in the block. It also had a large linear shrinkage and the rattler loss was 29.9% with 4.8% absorption. While it may be possible to produce a paver with this

material it is not likely that it would be considered seriously for the manufacture of a uniform tough paver.

The part of this experiment referring to the pugging by hand and by wet pan machine showed consistent gain in strength for the machine pugged clay for some materials, while quite the reverse action was obtained for a few others, but the fact remains that a certain amount of pugging is necessary to prepare shale so it will flow through a die of machine satisfactorily, in some instances causing prolonged hand pugging which approached the machine preparation in completeness of work done. There is no question that it is absolutely necessary to thoroughly prepare the shale before forming into ware, so as to get as uniform a texture as possible with a minimum of lamination and a freedom of included air.

Methods of Manufacturing

In connection with this testing of these eleven shales for the manufacture of paving brick an experiment was run on various processes of manufacture to see their effect on the structure and rattler test. Samples of shales were sent to various manufacturers of clay-working machinery and blocks made up on (1) roller expression machine, (2) dry press, (3) soft-mud, and (4) on a new machine which will be called a belt machine. This belt machine consists simply of two belts running between steel sides. They taper towards the discharge end and the clay is fed into it at the open end. This clay is gradually compressed as the space between the belts narrows down to the size of the die, through which issues a column of clay very similar to a stiff-mud column which is of course free of auger lamination. The belts are held to their proper taper by a series of rolls close together. Owing to the fact that this machine has not been released on the market, photographs cannot be shown.

Roller Expression Machine

The brick made on this machine were fired in the same kiln alongside of stiff-mud brick made with an auger machine and being made out of the same material and given identical heat treatment will give us a good comparison of the two processes. The block made on the roller expression machine had a rattler loss of 17.2% notwithstanding that there were five stops in running the test due to belt trouble, broken pulley and clutch slipping. The auger machine brick were tested under far more favorable operating conditions of the rattler machine and ran a loss of 19.7% or 2.5% greater loss than that of the block made on the roller expression machine. This machine in order to be a success has to have some arrangement to keep the clay from squeezing out at other places than the die.

Dry-Press Process

The shale used in making the block on this process was the same as used on the roller-expression machine, and was found to be too plastic to press well and many of the

blocks had pressure cracks in them. A significant factor introduced in this process was the fact that dry-pressing has the same effect on shale as on fire clays, namely, to increase the vitrification temperature as they are much more refractory than the block made by the other processes. Owing to this increase in refractoriness of the dry-press brick they were not nearly vitrified and it is hoped that opportunity will be had to fire them till they are vitrified. The rattler loss was 58.0% and the absorption was 8%.

This process does not seem to offer very favorable factors for making paving brick as most of the shales suitable for making pavers are too plastic to press well and there is a minimum bond produced. The texture is ideal, being free of air blebs and lamination.

Soft-Mud Process

Paving brick were made up of a shale from Lehigh, Ia., by the laboratory method and on a standard soft-mud machine and fired in the same kiln until thoroughly vitrified. The laboratory block had a rattler loss of 34.3% and 2.04% absorption and the soft-mud block had a rattler loss of 33%, its absorption being 2%. While both of these losses are entirely too high for a standard paver, still it shows that the soft-mud process compares very favorably with the usual stiff-mud process.

These tests invariably had about half of the brick broken in two and of course this ran the test high, as five unbroken bricks were checked and found to have only a 20.6% rattler loss. This breaking is due to the fact that the shale is exceedingly plastic and became brittle in firing so hard. It did not have the usual amount of siliceous material as used in the manufacture of sewer pipe.

Very plastic shales or clays are difficult to manufacture into brick on the soft-mud machine and the texture of this product is excellent, having neither auger nor die lamination, in fact the only defect is the small amount of air included producing air blebs.

Belt Machine Block

The brick made on this machine also had an excellent texture but unfortunately there was no laboratory brick made out of this shale although the deposit is close to a very similar shale which is making a successful paving block. The rattler loss averaged 36% with an absorption of 4.3%. This, of course, is too high for pavers, but may be lowered by firing to a higher temperature. It was quite a disappointment to find a block of such good texture free of air blebs and auger lamination run so high a rattler test and it seems well worth while to make further experiments on this machine.

Effect of Magnesium on Paving Block

In a report on paving brick by R. C. Purdy,[1] for the State of Illinois we find the following reference to the effect of MgO in ceramic mixtures:

[1] Illinois Geol. Surv., *Bull.* 9, p. 243.

(1) Magnesium oxide increases viscosity.

(2) Magnesium oxide gives lower rate of fusion, at least when it is predominating flux.

(3) Clays making good paving block contain larger per cent of magnesium oxide than calcium oxide.

(4) Italians make a tough low-fired porcelain in which magnesium is the only RO or fluxing base present.

The shale from Boone, Ia., was selected for the study of additions of MgO in small amounts, due to the fact that it ran just a little high in the rattler test and seems to be lacking in bond material.

The following is the chemical analysis of this Boone shale and the material used as a source of MgO.[1]

Boone shale		Magnesium oxide	
SiO_2	66.03%	SiO_2	0.62%
Fe_2O_3	5.27%	Fe_2O_3 and Al_2O_3	0.70%
Al_2O_3	15.67%	CO_2	6.87%
CaO	1.38%	CaO	1.95%
MgO	1.45%	MgO	78.85%
K_2O and Na_2O	1.38%		
Loss on ignition	8.94%	Loss on ignition	11.51%
	100.12%		100.50%

Paving brick were made up with constant additions of above magnesium oxide and were marked 66.05, 66.1, 66.25, 6.2, 66.3, and no difficulty was encountered in drying this set of blocks. They were all given the same heat treatment being fired in the same kiln together. The following curve (Fig. 3) gives the results of tests on these brick, also the exact amount of MgO in each set of brick as determined on the fired brick by chemical analysis. This variation in actual amounts of MgO and that indicated by the number following the clay number (66) which was the per cent added of the material when it was thought to be practical pure magnesium carbonate, is due to the fact that it was mostly the oxide of magnesium.

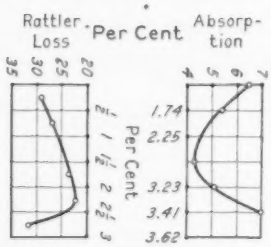

FIG. 3.—Effect of introducing small amounts of MgO from $MgCO_3$ to Boone shale made into pavers.

This addition of magnesium gave a marked degree of fluxing action to this shale and the characteristic red color was changed to a decided buff color similar to that of a No. 2 fire clay. The paver containing 1.74% MgO stood a rattler test of 27.8% loss, absorption 6.5% and 11% linear shrinkage. The color has not changed much, being still a distinct red color. The rattler loss steadily decreased as did the absorp-

[1] As made by G. W. Burke, Chemist.

tion and the linear shrinkage increased as the color changed to a decided buff color with increasing amounts of MgO up to a content of 3.41%.

This paver containing 3.41% MgO has a rattler loss of 22.4%, absorption of 5.1% and total linear shrinkage of 14%.

There is a sharp rise in the rattler loss and absorption of the paving brick made with 3% addition of MgO or the block having 3.62% MgO content, indicating that this has passed the amount which is most beneficial in making the paving block tougher as shown by the rattler test. The rattler loss of this block was 31.6% and the absorption was 7.02%, with 14.5% linear shrinkage. This small per cent of MgO was so bulky[1] that it amounted to about half and half by volume and it would be difficult to incorporate a greater amount of this same source of magnesium and get it thoroughly distributed throughout the shale.

Effects of Colloids The Boone shale was again used to try additions of colloidal material in order to observe the effect on the bond, as indicated by the rattler test. Two colloidal materials were used, one from Beatty, Nevada, and one from Watertown, Ia. One per cent was added to the shale and these were made up into blocks which were fired at the same time as the other brick. They were found to be very much too soft to give a good rattler test and the absorption was high, being 8.5%.

Some grog formed from tile made of shale from Nevada, Iowa, was mixed with 6% of bentonite and made into brick on the plunger machine in the laboratory. These were also found to be underfired at cone 1. A few of these were fired in a small kiln to cone 11 and at this temperature they were thoroughly vitrified. These additions of colloidal material indicate in all three instances an increase in the vitrification temperature as each was entirely too soft at the heat given to the other pavers.

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[1] EDITORIAL NOTE: Should have used talc. A small amount (2% or less) of magnesium carbonate would help greatly in forming the ware.

THE CALCULATION OF COAL EXPENSES IN ROTARY CEMENT KILNS[1]

By D. A. Tchernobaïeff

ABSTRACT

The results of the author's experiments upon the heat of formation of cement clinker are given, the formula for calculation of coal expense is deducted. For an easy application of the formula the author gives several tables, and, as an example, calculates the coal expense for the heat balances of C. E. Soper and T. W. Richards.

The Heat of Formation of Cement Clinker

To have a correct heat balance of a rotary kiln we must know the heat of formation of cement clinker.

The heat of formation of silicates and aluminates may be determined by the method of Le Chatelier,[2] consisting in the fusion of silica or alumina with metallic oxides or carbonates added with some fuel (charcoal) in a calorimetric bomb; the mixture is put in a case made of a strip of filter paper and ignited by an iron wire. The difference between the calculated (charcoal, paper, iron wire, etc.) and observed amount of heat ought to give us the sought heat of formation.

By this direct method I have found[3] the total heat of formation of cement clinker (by fusing the raw mixture of a Russian cement mill) to be equal from -308.4 to -309.8 cal. per 1 gram $CaCO_3$ in raw mixture, or the heat of formation excepting the heat of decomposition of $CaCO_3$ (-427 cal. at constant volume, according to Berthelot) from $+118.6$ to $+117.2$ cal. per 1 gram $CaCO_3$.

The direct method may be good in many cases, but we are never sure that we have obtained the sought silicate; the product may not be fused sufficiently, the reaction may remain incomplete; at last the product may be partially crystallized and may partially remain amorphous.

But we can work otherwise. We can fuse first a previously prepared pure, crystalline silicate (or, generally, previously prepared product of reaction to be studied, in this case ready cement clinker) with such a quantity of silica, alumina or any other substance, as to obtain a low melting slag and, secondly, the corresponding mixture of raw materials (in this case, the cement raw mixture) with such a quantity of silica, etc., as to obtain the same slag. The difference of the two observed heats gives us the sought thermal effect.

I determined by this indirect method the heat of formation of the same clinker and found the heat $= +115$ cal.

For two other samples of Russian clinker[4] I found the heat $= +106$ cal. and $+110$ cal.

[1] Recd. August, 1925.

[2] *Comptes rendus de l'Acad. des Sciences*, **120**, 523 (1895); **122**, 80 (1896).

[3] *Zeits. für angew. Chemie*, **24**, 337 (1911).

[4] *Annales de l'Institut Polytechnique, à Kieff*, **13**, 185 (1913).

For a third sample I found +166.7 cal. This figure seemed to me untrustworthy. To verify the result I made the same experiment, but instead of silica, as usual, I added my clinker and raw mixture with alumina. The observed amounts of heat were quite different, but the difference gave me the same figure, namely, +169.4. This proves the correctness of the method; as to the difference between the results for this and other samples of cement, I found it explained in an abnormally great amount of organic matter.

For a quite correct thermal balance we should therefore determine the heat of formation in every particular case experimentally; for an average balance I assume the average heat +110 cal. or the total heat = +110 − 443 = −323 large calories per 1 kilo $CaCO_3$ (−433 = heat of dissociation of $CaCO_3$ at constant pressure according to Berthelot) or −735 large calories per 1 kilo CO_2 in raw cement mixture.

Average Heat Balance of a Rotary Kiln

In calculation of an average (approximate) heat balance I assume the initial temperature of raw materials, air and fuel = 0°C. I take no notice of heat losses in dust and ready clinker (its temperature being only about 75°C in modern kilns). Some of these errors being positive and others negative, the total sum of errors can be neglected. I take the average composition of air-dried mixture as follows: loss of ignition 36.5%; CO_2 content 33.5%; water = 36.5 − 33.5 = 3%.

The quantity of added water (wet process) $h\%$ or $\frac{h \times 100}{100 - h} = m$ per cent of air-dried mixture.

As I have demonstrated in another place,[1] the volume of gases of combustion of 1 kilo coal may be approximately expressed:

$$D = 1.11 \frac{Q}{1000} + 1.07(n-1) \frac{Q}{1000}$$

where

D = the volume of gases at standard conditions in cubic meters
Q = the upper heat of combustion of coal
n = the ratio of air actually admitted to air theoretically necessary for complete combustion.

The excess of air I take 5%; n = 1.05. The specific heat of gases is taken according to Holborn, Hennig and Pier.[2]

At these conditions we have the following heat balance for 100 kilos of clinker:

[1] *Schriften des Kiewer Instituts für Volkswirtschaft*, **1**, p. 1 (1923).
[2] M. Pavloff, *Jour. of the Russian Metallurg. Soc.*, **1**, 421 (1912).

Heat input. The coal expense = x%, the lower heat of combustion Q' ..... $Q'x$ cal.

Heat output.

I. The heat of reaction is easy to calculate ..... 38,779 cal.

II. The heat of evaporation of water at 0°C, 607 cal. per 1 kilo, according to Clausius, gives us ..... $956m + 2868$ cal.

III. The loss of heat in waste gases at the temperature t°C:

(1) With CO_2 and H_2O vapor from raw mixture:

with H_2O ..... $0.0875\ (m + 3)a$ cal.
with CO_2 ..... $1.199b$ cal.

where a and b are the amounts of heat to warm 1 kilogram-molecule of H_2O and CO_2 from 0° to t°C.

(2) With combustion gases: The loss of heat with combustion gases

$$D.W.x \text{ cal.}$$

where D is the volume of gases per 1 kilo of coal and W the amount of heat to warm 1 cubic meter of gas at standard conditions from 0° to t°C. The values of W at 5% exceeding air are given in Table I.

TABLE I

$t°$ =	200	300	400	500	600	700	800	900	1000°C
W =	66	100	134	169	205	241	279	317	355 cal.

IV. The loss of heat by convection and radiation at experimental balances is usually calculated by difference.

As a first approximation I assume it is directly proportional to the surface of the kiln and the temperature of waste gases and inversely to the thickness of fire-proof wall of the kiln. From correct balances for some Russian and German kilns I have calculated that the loss is approximately:

$$\frac{S}{d.B}\ (20.9t° + 5688) \text{ cal.}$$

where S = the surface of the kiln in square meter
d = the thickness of the wall in meter
B = the quantity of barrels (170 kilos each) per day
$t°$ = the temperature of waste gases

As the sum of items of output is equal to the input, we get the necessary equation, and, by solving it, we obtain the following expression for coal expense:

$$x = \frac{1}{Q' - DW}\ (41647 + 0.2625a + 1.199b) +$$
$$\frac{1}{Q' - DW}\ (956 + 0.0875a)m +$$
$$\frac{1}{Q' - DW} \cdot \frac{S}{d.B}\ (20.9t° + 5688)$$

The first member of this expression gives us the coal expense at the dry process ($m = o$) and at the absence of convection and radiation losses.

The second member, the coal expense to evaporate the water and to warm the water vapor at the wet process.

The third member, the coal expense to compensate the losses by convection and radiation.

The expression $Q' - DW$ is the heat given by every 1 kilo of coal to the kiln as DW is the lost heat in combustion gases.

The Tables to Calculate the Coal Expense

To facilitate the application of the deducted formula, I have calculated the Tables II, III and IV giving the values of separate members of the formula at different temperatures of waste gases and different contents

TABLE II

THE VALUES OF THE FIRST MEMBER

$t°$ = the temperature of waste gases

$t°$ =	100	200	300	400	500	600	700	800	900	1000°C
I member =	6.17	6.64	7.18	7.78	8.46	9.24	10.14	11.19	12.40	13.82

TABLE III*a*

THE VALUES OF MEMBER II (WET PROCESS)

$t°$ = the temperature of waste gases, $h\%$ = content of water

$t°$ =	100	200	300	400	500°C
$h\%$					
30	6.33	7.06	7.86	8.78	9.79
31	6.63	7.40	8.24	9.20	10.26
32	6.95	7.75	8.64	9.64	10.75
33	7.27	8.11	9.04	10.09	11.25
34	7.60	8.48	9.45	10.55	11.77
35	7.95	8.87	9.88	11.03	12.30
36	8.30	9.26	10.32	11.52	12.85
37	8.67	9.67	10.78	12.03	13.41
38	9.05	10.09	11.25	12.55	14.00
39	9.44	10.52	11.73	13.10	14.60
40	9.84	10.98	12.23	13.66	15.22
$t°$	100	200	300	400	500°C
$h\%$					
41	10.26	11.44	12.75	14.23	15.87
42	10.69	11.92	13.29	14.83	16.54
43	11.13	12.43	13.84	15.45	17.23
44	11.60	12.93	14.42	16.09	17.94
45	12.08	13.47	15.01	16.76	18.68
46	12.57	14.02	15.63	17.45	19.45
47	13.09	14.60	16.27	18.17	20.25
48	13.62	15.20	16.94	18.91	21.08
49	14.18	15.82	17.63	19.68	21.94
50	14.76	16.46	18.35	20.48	22.84
60	22.14	24.69	27.52	30.78	34.25

TABLE III*b*

THE VALUES OF MEMBER II (DRY PROCESS)

$t°$ = the temperature of waste gases, $h\%$ = content of water

$t°$ =	500	600	700	800	900	1000°C
$h\%$						
5	1.20	1.34	1.51	1.70	1.92	2.18
6	1.46	1.63	1.83	2.06	2.32	2.64
7	1.72	1.92	2.16	2.43	2.74	3.12

$t°$ =	500	600	700	800	900	1000°C
$h\%$						
8	1.99	2.22	2.49	2.81	3.17	3.60
9	2.26	2.53	2.83	3.19	3.60	4.09
10	2.54	2.84	3.18	3.58	4.05	4.60

TABLE IV

THE VALUES OF MEMBER III AT $\frac{S}{d.B} = 1$

$t°$ = the temperature of waste gases

$t°$ =	100	200	300	400	500	600	700	800	900	1000°C
Member III	1.12	1.49	1.87	2.31	2.79	3.33	3.94	4.65	5.45	6.39

of water at the wet process. For the third member the values are given at $\frac{S}{d.B} = 1$ and must be calculated, in every particular case, as indicated, lower.

As a ground of calculation coal is taken with $Q = 7500$ cal. and $Q' = 7250$ cal. Coal expense is directly proportional to the expression $\frac{1}{Q'-DW}$. With an insignificant error we can in many cases take it proportional to the expression $\frac{1}{Q}$.

To show the use of the tables, I will calculate the coal expense for the kilns of the heat balances of E. C. Soper and T. W. Richards.

The Balance of E. C. Soper:[1] The raw mixture contains 53% of water ($h = 53\%$). Coal expense = 48.06%; the heat of combustion = 5608 cal. Temperature of waste gases = 236°C.

The length of the kiln = 30.38 meters, the diameter is 2 m. The thickness of the wall is unknown; I assume it to be 0.2 m. The kiln gives 166 barrels per day. Hence $\frac{S}{d.B} = \frac{\pi.2 \times 30.48}{0.2 \times 166} = 5.77$. We shall calculate the coal expense for the temperature 200° and 300° and then find the expense at 236° by interpolation.

[1] C. Naske, "Die Portland zement Fabrication," Russian edition, p. 149 (1913).

Temperature	200°	300°
Member I	6.64	7.18
Member II	18.96	20.08
Member III	$5.77 \times 1.49 = 8.60$	$5.77 \times 1.87 = 10.79$
The sum	34.20	37.99

For $t° = 236°C$ we obtain:

$$34.20 + (37.99 - 34.20).\frac{36}{100} = 35.56\%$$

And for the heat of combustion 5608 cal.:

$$\frac{35.56 \times 7500}{5608} = 47.63\% \text{ instead of } 48.06\%$$

The Balance of T. W. Richards:[1] The excess of air is unknown, but, as the gases contained 0.2% CO, it cannot be great and we commit no appreciable error by calculating for an excess of 5%.

The temperature of the clinker was 1200°C, and the loss of heat calculated by Richards is as great as 100,500 cal. per 100 kilos of coal or 345 kilos of clinker, hence the loss per 100 kilos of clinker is 29,000 cal. To compensate this we must burn $\frac{29,000}{Q'-DW}$ kilos of coal more, namely 6.01 kilos, at the temperature of waste gases 800°C and 6.46 at the temperature 900°C.

The coal expense was 28.98%; the heat of combustion according to Dulong's formula (calculated by me) = 7.395 cal. The temperature of gases = 820°C. The length of the kiln is 18.29 meters, the diameter, 1.829. I take d = 0.2 m. The kiln gives 233 barrels per day by dry process. Hence

$$\frac{S}{d.B} = \frac{\pi 1.829 \times 18.29}{0.2 \times 233} = 2.25$$

Temperature	800°	900°
Member I	11.19	12.40
Member II		
Member III	$2.25 \times 4.65 = 10.46$	$2.25 \times 5.45 = 12.26$
The loss in hot clinker	6.01	6.46
The sum	27.66	31.12

At the temperature 820°C: $27.66 + (31.12 - 27.66)\frac{20}{100} = 28.37\%$.

At the heat of combustion 7395 cal.: $\frac{28.37 \times 7500}{7395} = 28.75\%$

T. W. Richards gives 28.98%; one cannot desire a better coincidence.

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[1] *Jour. Amer. Chem. Soc.*, **26**, 80 (1904). C. Naske, *Zeits d. Vereines Deutscher Ingenieure*, p. 1354 (1905).

PRINCIPAL REFRACTORY PROBLEMS OF THE MALLEABLE CAST IRON FOUNDRY

By H. A. Schwartz[1]

ABSTRACT

The paper covers a brief description of the necessary conditions under which fire brick are used in air furnace melting, and outlines some of the elementary relations between fuel economy and refractory economy, including loss of use.

It has suggested as a ceramic problem, that the principal fields for improvement lie in developing refractories more resistant to slags for side walls, and more resistant to changes of temperature for furnace roofs. It is further suggested that unless higher refractoriness can be secured, the field for the use of heat insulation in such furnaces is probably negligible. The very refractory materials now known, seem to fail, due to a lack of resistance to thermal stresses.

This paper is to be considered as a brief summary of some factors affecting the performance of fire brick in air furnace melting. Its brevity and the fact that most of what the writer will have to say deals with metallurgy, and not ceramics, is merely an expression of his ignorance in the latter field.

It is quite obvious that the principal interest of ceramists in a metallurgical subject will be the opportunities of applying, within their profession, data gathered by the user of their material toward the end of an improvement in refractories, and the general benefit of all. Leaving the reader to make for himself the proper applications, the following discussion has been prepared.

In air furnace melting we are confronted with the necessity for combustion conditions, such that the final products will contain little, or no free oxygen, and a few per cent of carbon monoxide. The reason for this requirement is deeply rooted in the chemical equilibria between the gas and liquid phases in contact in the furnace. It is not capable of modification for any purpose whatsoever.

Under these conditions, the maximum flame temperature is possibly 3200°F, as actually measured in commercial furnaces. The temperature of the face of the furnace walls will be that at which heat input, by convection mainly, is balanced by losses by conduction outward and radiation from the furnace structure. This means in practice, perhaps 3000°F, the resulting metal leaving the furnace at temperatures about 2600°F.

If now the thermal engineer seeks to minimize radiation loss by using very thick walls, the inner face of the wall grows hotter, since the cooling action of the furnace exterior has diminished. He thus buys fuel economy at the expense of refractory economy.

In furnace roofs of "bungs," a thickness of $4^1/_2$ inches is almost the universal standard. Probably this has been arrived at as the best balance

[1] Recd. Jan. 26, 1925. Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, Feb., 1925. (Refractories Division.)

between brick, labor and fuel economy. In side walls, thicknesses from 18 to 9 inches are in use. The former fail, in the beginning, quite rapidly in the writer's experience. Very probably 9-inch walls would be ideal if there were not a desire to break joints at least once in the thickness of the wall. As a matter of fact, were it not for the mechanical instability of very thin walls, a thickness of from $4^1/_2$ to 6 inches might be maintained indefinitely by some method of exterior cooling.

The best economy in both fuel and brick, with which the writer is familiar, was obtained on furnaces with 12-inch walls. Heat insulation would seem to hold out no promise of merit, for it would result, probably, in the rapid destruction of the inner refractory linings. The heat capacity of furnace structures is also of importance. The conductivity of clay refractories is not so great but that considerable time elapses before they reach their final equilibrium temperatures. If the structure be allowed to cool over night, they actually will not ever reach equilibrium in service, and hence, will survive more hot hours than when continuously operated. Air furnaces operated twenty-four hours a day have required major repairs in less than a week, while, when operated sixteen hours a day, they would require much less repair after two weeks.

Erosion by flue gases is an important source of wall destruction. The flame must move sufficiently rapidly through the hearth to produce the circulation in the bath required for quick heating. It carries with it a spray of slag and iron particles, which flux the roof and walls, and the friction of the hot gases drags this softer material off and carries it along. Wherever constrictions occur, or parts project sharply into the stream of gas, rapid cutting occurs.

Most furnaces use "top blast" and if these streams of air are so directed as to strike a wall, the brick is very rapidly cut out by a combination of melting and erosion.

Somewhat fantastic roof forms were formerly rather common, and it was also thought that the top blast would force the flame away from the roof. It is very doubtful whether either arrangement has any merit whatever, and the writer is committed to a roof which in profile is nearly straight, but dips down toward the stack.

The character of the fuel is also of importance. Most air furnaces are grate fired, using forced draft. Most coals, so fired, blow particles of coal, coke and ash up into the gas stream, which impinge on the roof over the fire box. Depending on the character of the ash, it may flux the brick and cause roof failure, or it may stick as a spongy mass, and protect it.

Coal also differs in the time required for its gaseous decomposition products to unite with the air supply. If this time be very short, a high temperature may be realized before the gases strike the fire box roof, and much damage done. It is one of the functions of the top blast to avoid the

possibility of complete combustion, and hence maximum temperature occurring before the flame has come into contact with the charge. With pulverized coal there is an advantage in that the burning mass travels always along the length of the furnace, and hence need not impinge on the walls or roof at its point of maximum temperature.

In the early days of oil burning, such hot localized flames did a good deal of destruction to brickwork, although in later installations this has been largely overcome. There is now a distinct feeling that both pulverized coal and oil are less destructive to furnace linings than is hand fired coal. Whether the point is capable of rigid proof is somewhat doubtful. Some indirect effect through chemical action may also be expected, for any system which uniformly regulates the combustion, will avoid accidental over-oxidation of the charge. The products of such oxidation are very destructive to clay brick.

The writer has in the past touched upon the chemical action of slags. During the progress of each heat the slag changes progressively from molten Fe_3O_4 to acid ferrous silicate, resulting in a serious problem to the ceramic chemist, who wishes to minimize its fluxing action on his product.

In furnace roofs we are confronted with mechanical difficulties. Too round an arch results in an unfavorable flame distribution, too flat a one imposes too high stresses on the "bung frame."

The life of bungs is enormously influenced by their mechanical rigidity. It is within our knowledge that a mechanically more stable design more than doubles bung life. Bungs are used 9, 13, 18 and 24 inches wide. Where crane service is available the 24-inch bung is much the most economical, although the 13-inch size is, perhaps, the commonest. Only considerations of the weight which can be handled without abuse should limit bung width. If the brick are to be held firmly, they must be strong, not cracking under pressure. Also, since variations of temperature are unavoidable, they must resist this condition.

Conclusions

The temperature and chemical composition of flue gases, the composition of slags, and the temperature fluctuations due to charging are virtually fixed quantities which neither the producer nor the consumer of brick can alter. The method of firing, the fuel chosen, the design as to form and material of the furnace walls, are within the limitations of available material within the metallurgist's choice.

The melting point of the refractories, having regard also to the fluxing action of slags or ashes, now sets some limit on the degree to which he can reduce radiation losses. Were there a chemically inert refractory of a melting point above the theoretical temperatures of combustion of his fuel, he might thicken his furnace walls and economize on heat. Such

thickening would, perhaps, have to be in the form of increase in number of layers of refractory to avoid increases of stress due to greater thermal gradients in individual shapes. On the other hand, were the brickmaker relieved from the need of considering chemical destruction of his product, the admissible temperatures would at once be increased.

Some of the artificial refractory minerals, spinel, sillimanite, etc., hold great theoretical advantages. In the present state of the art they seem to lack resistance to thermal stresses. If the problem be viewed merely as a reduction in the amount of refractories used, and in the interruptions of service for repairs, a thin walled, artificially cooled furnace might furnish the solution at an undetermined increase in fuel costs.

It is very doubtful whether all the variables here alluded to could be combined into an equation from which, given the unit costs, the most economic practice might be calculated. It is much more likely that the operating executive will continue to arrive at his results by a process of trial and error in an attempt to find the fuel, refractory and design which reduces his cost for labor, material, overhead and losses due to interruptions in service to a minimum.

In the present state of the art, it is probable that the ceramist's efforts may be most profitably applied in the direction of improving the resistance of side wall brick to the chemical action of slags and of bung brick to mechanical destruction by thermal stresses and perhaps the stresses applied by the bung frame. So far, the best solutions seem to have been based on the making of very dense brick for the former, and coarse, open brick for the latter.

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REFRACTORY REQUIREMENTS IN THE GRAY IRON FOUNDRY[1]

By Richard Moldenke

ABSTRACT

The author calls attention to the lack of information on foundry refractories on the part of both foundrymen and makers of refractory materials. The applications of these materials in foundry practice are enumerated, and the requirements detailed sufficiently to enable the manufacturer to select the proper grades of brick and clay for cupola and air furnace operation, as well as for the lining up of ladles.

Introduction

The refractory requirements of the iron foundry are of prime importance in that industry, as will be understood by recalling that from the melting of the iron mixture to the removal of the cold castings from the foundry floor all containers for the molten metal must withstand extremely high temperatures. And this is the case whether the castings be of any form of iron—gray iron, malleable cast iron, which in its original form is white cast iron, and steel.

While the foundryman is perfectly aware of the fact that insufficiently refractory materials are the cause of much loss to him in the melting, pouring and subsequent cleaning operations, neither he nor the producers of these materials are always sufficiently familiar with the subject to know just what to do. Further, the force of habit is such that foundrymen will keep on digging clay for daubing their ladles on their back lot, and dealers in refractory materials will not study the co-related foundry problems involved in order to supply what is required. Nor will they follow the situation on the ground, and thus familiarize themselves with the processes used so that they may put their fingers on weak points, and help make the necessary corrections.

The result of this situation is that the foundrymen themselves, through specially constituted committees of competent bodies, are taking a hand in the game of refractories, and we now have a thorough investigation of the molding sand problem going on in America, with work along the same lines prosecuted in Germany. Also, a remarkable development of loose refractory materials for foundry work going on in Germany, with similar studies in the way of high temperature bonds by the makers of refractories under way here. It is purposed, in what follows, to itemize the foundry processes involving the use of refractories and to discuss the requirements in sufficient detail to allow the maker of refractories to draw the necessary deductions.

Foundry Refractories

Cupola

The refractories used in the lining of cupola is in importance next to the molding sands.

[1] Recd. Dec. 15, 1924. Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, February, 1925. (Refractories Division.)

Disregarding the crucible as obsolete in the iron foundry, leaving the open-hearth and the electric furnace for discussion under refractories for steel castings, there remain only the shaft or cupola furnace and the reverberatory or air furnace to be considered here. Gray iron—as also white cast iron, is melted in these two types of furnaces in enormous tonnages and under temperatures and other physical and chemical conditions which make it highly important to use the proper refractories in their right places. The cost accounts of foundries make special provision for fire brick and clay used in cupola and ladle repairs and maintenance, and where much and very light steel scrap is charged—as in making sash weights—the item of refractories is a heavy one.

The cupola, which melts the bulk of the iron used for gray iron castings, is a cylinder of refractory material held in place by a steel shell, into the top of which are charged alternate layers of metal and fuel, with air blown through from below. Iron melts in a comparatively small zone about two feet above the blast entrance and is collected in the crucible of the shaft to be tapped out and poured into molds. The operation of melting is as continuous as may be wished, subject to the lasting of the refractory lining at the melting zone.

The Charging Zone There are three requirements to be met by the lining. First, as the metal is charged the lining must be able to stand terrific abuse, for there is to be considered not only the blow of the jagged-edged heavy pig of iron as it is thrown in, but also the abrasion of a rigidly packed gridwork of iron tools—as it were—cutting their way along the lining as they descend. The temperatures themselves are not very high here, though still high enough to require refractories instead of a metal lining, as otherwise the steel shell will buckle and endanger the structure. Coarse-grained, friable fire brick are out of question here, and there is indicated a hard, dense, fine-grained brick still refractory enough to hold the heat from interfering with the life of the shell.

Above Melting Zone As the charges descend to fill the place of those melted away, they become heated more and more until arriving at the melting zone the metal softens and drops away. Hence, one or two feet above the melting zone top—depending upon how much blast finds its way up along the lining—there is very little abrasion but the temperatures become important.

The Melting Zone When the melting zone is finally reached and the iron runs from the melting charge in drops and little rivulets, the refractory lining must not only stand the maximum temperature of the superheated molten metal (for the drops of metal have little chance to become hotter than they are when they part from the pig and scrap) but the much higher temperature of the fuel bed it is in contact with. That only the very best of refractories will stand up here is shown by the

fact that when poorer grades of brick are used even a comparatively short run will melt out the material to a point endangering the cupola. In such cases the melting zone may have to be refined after every heat. Hence the second requirement of high refractories.

Slagging Action of Charges

So far as refractoriness is concerned a high grade, coarse grained and perhaps friable brick might stand all right in the melting zone and below it right to the bottom of the cupola, were it not for another factor to be considered. This is the slagging action of the charges. As the coke used for fuel burns away, at least 10% of its weight remains behind as ash. As the pig iron melts, if sand-cast, there will remain some sand and gravel; similarly the burnt molding sand on the gates and sprues of the castings made the day before, if these be not cleaned by rumbling. All this material remains as the molten iron runs away from it, and is picked up by the calcined limestone arriving at this point at the same time. Hence, a slagging action is exerted upon the lining already under an extreme of temperature. It is highly important therefore, that the refractory lining be so constituted that as few joints as possible be searched out and entered into by the slag at hand. Hence the disadvantage of coarse-grained refractories here also. The third requirement of cupola refractories, therefore, is a high resistance to slagging action.

Repairing of Linings

Above Melting Zone In general, the attempt is made to combine all three requirements in the same brick, as it does not pay to differentiate in the classes of brick used for the lining above and below the top of the melting zone except in the larger foundries running a number of cupolas constantly. Once the upper portion of a cupola is lined with a good strong, fine-grained fire brick and the charging door still has an apron covering that part of the lining, with perhaps some cast iron blocks inserted in the lining at danger points opposite the door, nothing need be done in the way of repairs for many months of steady service.

Melting Zone The portion of the lining at the melting zone and below this is quite another matter. Here, repairs are obligatory after every heat. If charging has been done properly the cutting action of melting iron and slag should be confined to a belt from six to nine inches wide, situated from 16 to 18 inches above the top of the tuyères at its lower border. If the charging system was improperly arranged, this belt may begin six inches above the top of the tuyères and extend three feet upward. Depending upon the quality of the brick and the handling of the cupola, this cutting into the lining may be but half an inch at its worst, but where periodic metal charges might have

consisted of large-surfaced salamanders the deflection of the hot gases against the lining in going upward must of necessity have cut deeply into the brickwork.

Daubing

Repairs are performed ordinarily by chipping off adhering material from the cupola run down to the slag glaze on the brick, and then daubing up the lining to a reasonable condition of fitness for the next run. The desire, of course, is to bring the lining back to the original dimensions, and hence, where the cutting has been deep there are inserted into this daubing pieces of fire brick, or even whole brick, as also large flakes of mica schist.

The point of interest to the maker of refractories is the composition of the "daubing," which consists of clay and fire sand so proportioned that there may eventuate a minimum of shrinkage. The fire sand used is usually good enough so far as refractoriness is concerned, but the clay in question is often lamentably wanting in this respect. Since this daubing is generally the same material used to prepare the ladles for containing the molten metal to be poured into molds, these items can be taken up together.

In daubing up the cupola with poor clay the consequences are very disagreeable, particularly as the melter who puts up with such poor material is usually a poor workman too. Instead of chipping out the cupola so that some proportion, at least, of the lining surface at the melting zone is cut clear down to clean brick, he will simply rip away projecting scoria and then proceed to daub on the clay-sand mixture, if necessary in successive layers, until the desired thickness is reached. When this thick mass—with enclosed brick often three inches in spots—right in the hottest position, becomes incandescent in the early part of the heat, and the slag coating of the lining it rests against softens, the whole of the daubing slides down and must be slagged away or bung up the cupola badly, besides offering the badly cut up melting zone of the lining to further attack. The writer has known of cases where a wheelbarrow full of daubing had thus slipped down daily to be slagged away at the cost of much coke and limestone, and the melting zone of the cupolas required relining to the shell every week. It cannot, therefore, be emphasized too strongly that none but the most refractory clay—of good fatness—should be used about a foundry, as it always pays good returns.

New Method of Lining

There is a new situation coming forward in the foundry in the way of lining up cupolas and repairing such linings. It is a German development in line with many of their forced economies. Fire sand is mixed with suitable clay and rammed directly into place in a cupola between the shell and movable forms of the desired interior lining diameter. The lining thus becomes a single mass, and when of proper composition, dried out slowly and heated carefully, is said to be as good in practice as a brick lining, and

of one-thirtieth the cost, over there. This new material, called "Stampfmasse," which translated can either mean a material to be rammed or "loam" to be rammed, is now sold in enormous quantities for all kinds of furnace linings, being in effect raw fire brick; and is now even put up into blocks, half blocks, and quarter blocks of the desired diameters of cupolas, under hydraulic pressure, to be tamped together with loose material into one solid mass. Once a slag glaze is formed on this lining, it answers just as well as regular brick, and can be patched up without any difficulty. Ground fire brick can be used in place of fire sands, just as is the case with our high temperature cements. Inasmuch as a development of this kind, which is capable of considerable economy in foundry melting operations, is bound to be followed up here shortly, it would seem well for manufacturers of refractories to anticipate the demand by studying the situation from the American founders' standpoint and getting in position to furnish both bonding material and refractory fillers in quantity and at entirely different prices than are the rule today for high temperature cements. Otherwise this coming business will get into other hands.

Refractories for Ladles

If there is any place in the foundry where the most refractory clay should be used it is for the repair of the melting zone portion of the cupola, as this registers the maximum temperatures dealt with. Again, if there is any place where it is important to retain a high degree of heat as long as possible, it is in the ladles carried about the foundry to pour off the molds. And yet, just here is where carelessness is the rule, for if a foundryman can get access to a local clay bank he thinks will serve his purpose he considers himself fortunate. If the clay is only fat enough, its refractory qualities are hardly considered. Hence his ladles must be lined very thick to prevent premature skulling and molds misrun and short poured because of cold iron, not to consider the reduced weight of molten metal carried. The use of a very refractory clay with fire sand in lining up the smaller ladles of the foundry, and for daubing the large ladles lined with fire brick, will mean a comparatively thin wall between the molten iron and the ladle steel to check radiation outward and consequent retention of heat where it is needed. It looks very bad to see the men go about with ladles showing red spots once they have been filled a few times.

Core and Annealing Ovens

There remains but to mention refractories used for furnaces as used in the foundry. Core and annealing ovens, requiring merely heat resistance —light in the first case, just below melting iron in the second—are lined with the cheaper product of the high grade refractories plants, or usually the "seconds" of the highest class brick. It is only when an air furnace

has to be used in a foundry that this matter must be considered seriously, and then it will be found that abrasion plays no important part; but resistance to high temperatures, and also strong resistance to slagging action are essential. Not only the slag line of the furnace hearth must stand up against corrosive influences, but sides and roof are peculiarly subject to slag and iron particles thrown up against them when the bath is in violent ebullition. Hence, a very fine-grained refractory clay brick is preferable where roof and sides are close to the bath. Where the roof is high, as in the case of the usual air furnace of a gray iron foundry for chilled rolls, or where very large pieces of scrap must be melted, the roof brick can be of coarser grain, provided the refractoriness is everything that can be desired.

In conclusion, the writer wishes to emphasize the fact that even though gray iron has a lower melting point than steel, this should not mean that lower grades of refractories will do for it. The melting zone of a cupola is the hottest known except that of the electric furnace. And even in the lining of ladles, an unnecessary slight drop in temperature of molten iron —through a poorly refractory clay—say for pouring radiators, will result in lost castings to such an extent that the money loss is hundredfold that of the additional cost of a good clay used for daubing material. Hence, "the best is only good enough" even in the gray iron foundry.

WATCHUNG, N. J.

Discussion

M. C. BOOZE: The Refractories Manufacturers' Association has had for several years an industrial service committee and one of the sub-committees has been on the refractory for foundry use. The purpose of the industrial survey work is to get data on refractories. We have attempted from time to time to get in touch with the Foundrymen's Association to get data and I believe we have failed to get answers to letters.

It is stated in the paper that the "rammed in" lining is coming into use. It seems like bad practice to me.

F. J. KENNEDY: I am connected with the Foundrymen's Association. The average foundryman does not have enough available reading matter on this valuable subject for his information. We know there is information available and we are planning and hoping that we can now have a joint committee to distribute this information to us. There are a few plants which have research departments and they solve their problems but the great trouble lies in the educating of these men so that they will be up in the matter.

As a rule the foundryman uses the nearest available and cheapest material. It is for us to get more papers and more information through the press as an educational matter.

A. F. GORTON: I agree with the last speaker that the foundrymen have come forward with some of the results of experiments with their refractories. The refractory people are not in position to experiment directly but the foundrymen are. There are many important questions to be investigated, for instance, molding sand, core sand in particular, lining of the cupola and the ladle. Experimental work is being carried out on molding sand and possibly on core sand. The core sand for malleable practice is possibly more important than the molding sand and a whole lot of work remains to be done on synthetic molding sands. We are doing some of that work ourselves and I would like to hear from these foundrymen who are conducting such investigations.

Dr. Moldenke speaks of the use of cheap clay and its value in the foundry. A similar case happened at our foundry. They got into trouble one time and wanted to get some brick in a great hurry in order to line the melting zone and they were given some zircon brick. They did not stand up at all but slagged down and ran like so much water. Probably the iron content of loam and cheap clay is the reason for the superior service of such materials when in contact with the molten metal.

W. G. OWENS: I believe in some of the smaller foundries that misuse of the brick has something to do with failures. Perhaps they should have ordered three grades of brick instead of using one grade in various zones of the cupola, for lining the ladles and for other purposes.

We know that the big steel plants, or the big blast furnaces would not think of using the same grade of brick in various zones of their blast furnaces and while the cupola is much smaller foundrymen could get much better service from brick in the upper zone if they would use hard, dense brick.

I know of a foundry that was using a high grade brick in the iron ladles and suggested they were using a too high grade brick and they made the substitution of a cheaper brick. They got more than 100% more life out of the cheaper brick, which cost them about $30 instead of $45. One trouble with the small foundries is that they are using just one grade of brick instead of using three grades of brick. Brick must be chosen that are best suited for the particular service encountered.

R. MOLDENKE: Referring to attempts on the part of committees on refractories to get information from foundrymen on this subject, I fear that these users of refractory materials know so little about the subject, other than that they observe the results, that questions sent out simply cannot be answered by them. Even in the few laboratories in foundries (compared with the great number of the foundries themselves) there are not many men familiar with the manufacture of refractories. Otherwise, there would not be so much trouble and loss to contend with as the result of poor or unsuitable materials. Only close coöperation and continuous

testing of the several products of the refractories establishment right in the cupola and ladles of the foundry will give the desired information. Unquestionably differences in charging and melting methods, as well as the character of the pig and scrap charged, not to speak of the fuel and fluxes used, will make differences in the reaction upon the refractories. It is true that good cupola block very closely laid will give better life than any lining that can be shoveled in loosely and rammed between an interior form and the cupola shell. However, the comparatively high cost of refractories in Europe has compelled this new method of firing the lining in place. Since cost data have shown the method to be one-thirtieth the cost of putting in brick or blocks over there, it is but natural that the method will come here eventually. It would have come into use here some time ago had not the selling price of the so-called "high temperature cements" which form the basis of the method been held so high. The expansion of the ramming up method in Europe to the great extent it has assumed would indicate that the results must be eminently satisfactory.

The instance mentioned of too high a grade of brick used in lining up a ladle is undoubtedly correct in that a cheaper brick gave longer life to the lining, but it should not be forgotten that cheaper brick are usually less refractory than the best qualities. This means a quicker cooling of the metal during transit and waiting to be poured. This, in turn, means more lost castings. So that it is not the getting of inferior grades of brick that should be considered insofar as the life of a ladle lining is concerned, but the character of the very best brick to be had to do the work properly, that is, the fineness of grain structure, resistance to slagging action, etc.

L. C. HEWITT: Relative to the conditions present that might affect the life of the block, it would be of interest to develop whether or not the majority of cupola slags are acid or basic, and what is the exact influence of fluxes such as limestone and fluorspar upon the lining. It has been my understanding that the majority of cupola slags are, perhaps acid in character but that slags in the same cupola on the same day may change from acid to basic, as fluxes such as limestone are added, depending upon quantity used.

Relative to the prime requisites of melting zone block, refractoriness, freedom from impurities, density and chemical composition as affecting resistance to slag action would seem to be the chief factors.

It would be of interest to learn whether or not the most desirable silica-alumina ratio of melting blocks has been determined or whether it is possible to determine such a ratio which would be applicable to all types of cupola service, considering, of course, the melting zone proper.

THE EFFECT OF VARIATIONS IN CUPOLA PRACTICE ON THE LIFE OF THE REFRACTORY BLOCKS[1]

By James T. MacKenzie

ABSTRACT

This paper discusses chemical, mechanical and physical influences acting on cupola linings and their combined effects. A brief description of common practice in lining, preparation and charging of the cupola is followed by a discussion of the effect of the daubing practice, the character of fuel, metal, flux and blast. The principal point of the paper is the injurious effect of oxidation resulting from thin or rusty scrap and from too high velocity of the blast.

The life of the refractory lining of the cupola furnace depends on its successful resistance to three direct influences discussed as follows:

1. Chemical The solvent action of the slag and the chemical union of the basic oxides of the charge with the silica of the lining. The action of iron oxide at high temperatures in the presence of molten iron is more severe than is commonly known, a very illuminating experience being the search for a crucible material described by Messrs. Tritton and Hanson in a paper on "Iron and Oxygen" read at the Fall Meeting of the Iron and Steel Institute (1924). The authors state that crucibles of silica, china clay and alundum were tried, "in none of which was it found possible to hold molten iron containing much oxide for more than a few minutes owing to the rapid attack of the pots by the oxide."

2. Mechanical The actual grinding off of the blocks by the descent of the charge and the ascent of the gases carrying suspended particles of abrasive or corrosive materials. Sharp corners on large pieces of coke and iron are particularly destructive in the stock, while sand and fine coke are preëminently abrasive when caught in the blast. Slag is also blown considerable distances up the stack and freezes onto the brickwork.

3. Physical The actual melting off of the ends of the blocks in the melting zone where temperatures of 1600°C and over are encountered. The spalling of the blocks and rupture of the mortar joints when subjected to changes of temperature incident to intermittent operation. Abuse in operation such as rough treatment of the lining in chipping, drying and charging.

It is evident that these three forces are all at work together and each one exerts a profound influence on the resistance of the block to the other. For instance, the impregnation of the blocks above the melting zone by slag and iron oxide, though not sufficient to cause them to melt off, accelerates the mechanical and physical losses by making them brittle and very sensitive to temperature changes. Conversely, the continued erosion at

[1] Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, February, 1925. (Refractories Division.)

this same point constantly exposes a fresh surface to the slag attack. The rupture of the mortar joints from physical causes allows slag to attack the block on greatly increased surface area and often allows the blast to escape through them carrying slag, grit, dust, etc.

To place before this body the effect of variations in practice on the life of the blocks a brief statement of the operations involved is in order. Starting from the shell of riveted or welded steel plate with openings for the charging door, tuyères, slag hole and tap hole, and the tuyères in place of the size number, and disposition specified by the builder, the lining of blocks is put in. Angle irons are usually provided beginning two or three feet above the tuyères and at intervals of about three feet to the charging door. Blocks are laid from the mantel to just above the charging door unless iron blocks are used at the latter point, when a belt of the latter about three feet in width is put on top of the refractories. These are very valuable in long heats when most of the charging is done after the cupola is filled. The utmost care is taken in the lining of the hearth and from the top of the tuyères on up to see that the brick lie in immediate juxtaposition with as little grout as possible, the brick being chipped out for angle irons, buckles in the shell, and anything that tends to interfere with the "brick to brick" ideal. Courses are staggered so that vertical joints do not coincide.

The lining being in, it is painted with a thin wash of fire clay and dried thoroughly without forced draft. The shell should become too hot to touch before this firing is finished. The bottom is dropped, the surface allowed to cool, another application of thin mortar made to the surface of the blocks, and the furnace is then prepared for the heat. The doors are put up, bottom rammed in, and enough wood put in to insure the ignition of the coke. Approximately two-thirds of the bed coke is now thrown in and the torch applied. When the wood is all consumed and the coke shows red all around the edges and at all the tuyères the bed is brought to the proper height with such of the remaining coke as is necessary, using a measuring rod to insure accuracy. (The modifications for oil or gas lighting are obvious.) The tuyères are now closed, the breast put in and the furnace is ready for charging. Steel, if used, pig and scrap, in the order named, are dropped carefully into the furnace, taking every precaution to avoid striking the walls with any of the heavy pieces, and at the same time giving the charge as good distribution as possible. A charge of coke is now put in evenly, followed by the stone, and successive charges of iron, coke and stone follow with more and more emphasis being placed on distribution and less and less on possible damage to the lining as the stock line approaches the charging door. When this point is reached the furnace is ready for the blast.

The blast enters through the tuyères and, passing through the ignited

coke, burns it to carbon dioxide with evolution of heat the reaction being chemically expressed as:

(1) $$C + O_2 = CO_2$$

The dioxide passing over the heated coke reacts with it to form monoxide:

(2) $$C + CO_2 = CO$$

This reaction, being endothermic, tends to cool the blast, the maximum of dioxide and the minimum of monoxide and oxygen occurring at a roughly conical surface usually some twelve to twenty-four inches from the tuyères—the distance depending on the velocity of the blast and the reactivity of the coke. The "melting zone" of the cupola may be described as the region beginning where reaction (1) has raised the temperature above the melting point of the iron and ending where the reaction (2) has reduced the temperature below that point. There is of course a great amount of heat absorbed by the iron in melting, but the fact remains that there is still a distinct melting zone even in the absence of iron.[1] Ordinarily this zone is about four inches deep and the greatest destruction of the refractories occurs at the point where it intersects the lining.

The first action of the blast, then, is to burn away enough coke to allow the metal of the first charge to come down into the melting zone, it having been preheated by the passage of the hot gases around it. It is there melted and trickles down through the coke to the hearth whence it is drawn off as required. The ash of the coke, the sand of the pig, and the stone combine to form slag, which follows the iron down and is drawn off from time to time as it accumulates, or is sometimes allowed to run out on top of the iron, whence it is removed in various ways not interesting here. By the time the charge is melted another charge of coke drops into place and the process goes on. It is evidently necessary to have enough coke in the charge to fill the melting zone completely and it is equally necessary not to have more iron in the charge than the coke in the melting zone is able to melt, otherwise the bed coke would be used up, the iron allowed to come down to the lower temperature, higher oxygen region—the iron burned, the refractories damaged, and if the bed is not quickly replenished melting stops and the bottom must be dropped—in fact the writer has had several experiences where dynamite had to be used to get the mass out of the stack after such an occurrence.

When the required amount of iron has been put in, charging is stopped and the cupola blown out. This is a trying time for the refractories for there is no fresh cold stock going in to absorb heat and filter the drops of slag and iron out of the blast. Inspection at this time will show a veritable shower of these and particles of white hot coke shooting up first around the edges and gradually from the whole bed, many of them sticking

[1] Belden, U. S. Bur. Mines, *Bull.* **54.**

to the brickwork. The particles of iron stuck to the wall burn as soon as the air strikes them, leaving a spot of iron oxide to cause damage on the next heat. When melting is done, the doors are dropped, the refuse removed and the furnace is cooled.

It is then prepared for the next heat by chipping out all the slag, coke and iron adhering to the walls, especially around the tuyères where it is chilled by the cold incoming blast. The melting zone is then repaired by "daubing" it with a wet mixture of clay and sand, using brick or even blocks if it is deeply attacked. The daubing should practically restore the straight line of the original brickwork but should not be allowed to encroach on the shaft area. The operations as outlined above are now repeated except that the wood and coke should be put in with due regard to the preservation of the daubing and that the first coke should be allowed to get quite hot so as to dry the daubing thoroughly before charging is begun. The first charge especially should be put in meticulously, for if any considerable amount of mud is knocked off of the wall the blocks are left exposed, and the tuyère below is very likely to be bunged up for the heat.

A general inspection of the brief summary above shows that we have three principal factors to consider: the lining, its chemical character and its physical condition; the stock, its chemical character and physical condition; and the blast, its velocity and temperature.

The Lining

It is not the purpose of this paper to discuss the properties of the blocks themselves. It is assumed that they are true to shape and free from visible defects which is generally true of the products of reliable makers. That they should be kept out of the weather is possibly not as generally known as it should be, for serious deterioration occurs upon exposure, especially if subjected to alternate freezing and thawing.

Probably the most important item in the lining of the cupola is the clay used as a grout. Unless this is as refractory as the blocks, it melts away leaving them exposed to the destructive influences and may even dissolve some of the blocks in melting. This point is stressed particularly by Dr. Moldenke (P. I. F.) who states that unusually poor results with linings are invariably traced to the use of local clays of low melting point.

The integrity of the lining is of fundamental importance and calls for the highest skill of the brick mason. Each block should lie snugly against its neighbors with the least possible amount of filling and should fit closely to the shell. Defects in the shell often cause considerable trouble in this respect—buckles, rivets and even the desirable angle irons contributing in no small degree to the failure of the blocks. Welded shells offer quite an advantage in this regard, as the troublesome rivet is entirely eliminated, which, even though countersunk, persists in working loose under the con-

tinual vibration, contraction and expansion and allows the blast to escape through any channels that may have opened up through the refractories.

It is safe to say that daubing the melting zone is the real *bête noire* of the cupola tender. Here we have a ring around the cupola melted out of blocks which are the utmost effort of the experienced and well equipped manufacturer, placed in position by a highly skilled artisan working under the most favorable conditions. The tender now has some clay and sand, a mud box and a plasterer's hoe, a hose or perhaps a bucket of water, and a half hour's time with which to repair the lining for another heat. The curious thing about it is not that he so frequently fails but that he ever succeeds. His mud must be wet enough to work easily, but if too wet it will crack and perhaps blow off when heated. It must be sticky enough to adhere to the glazed surface of the blocks, open enough to dry without cracking, and refractory enough to withstand the high temperature of the furnace. There are probably as many different daubing mixtures used as there are cupola tenders. In many small foundries a smear of strong molding sand is all that is attempted, but in long heats the mixture of clay and fire sand described by Dr. Moldenke (P. I. F., p. 380) is almost universal, the percentages naturally depending on the fatness of the clay. The mixture used by the writer for many years was one-fourth each of a very fat yellow clay, a rather lean fire clay, silica sand and crushed fire brick. This batch had excellent properties except for its melting point, which was low on account of the highly ferruginous yellow clay. Recently, there has been available a very fat, highly refractory fire clay which has eliminated the other two clays—the mixture now being one-third each fire clay, sand and crushed fire brick prepared as before in a mill. The improvement in the appearance of the furnaces at the end of the heat has been most remarkable since this new clay came to hand. In long heats where the cutting under the best conditions runs as much as three or four inches, the daubing should be used simply as a seating for brick placed flatwise in the ring. Splits are very useful for this purpose and should always be kept on hand. Mica schist is very convenient and satisfactory, though it is not at all porous and the lining must be heated carefully if large pieces are used to prevent the steam blowing them off.

An important factor is the time allowed by the working conditions of the foundry for getting the furnace ready for the next heat. In plants using short melts this is of little concern, but where a cupola is run all day and must be ready for charging early the next morning the temptation is strong to bring the cupola men out as late as possible and rush the work. This usually results in a very poor job—the chipping is not thoroughly done, the daubing is not carefully put in, the wind is turned on to hasten the lighting off, and the charging is done helter-skelter. It is far better to have the

furnace put up at night on a separate shift—then everybody has time to do the job well. Often this requires cooling off the walls with a hose so that the men can work in the shaft, which sounds like bad treatment and probably does injure the lining, but good blocks stand it remarkably well. Curiously enough the blocks seem to give better service when the furnace is run every day, even though cooled with water, than when run every other day and consequently allowed to cool naturally. The writer has three distinct conditions to handle, a description of which is interesting in this connection. First are the large pipe foundry cupolas, two running every day and two every night. The heats are about ten hours in blast, melting fifteen tons per hour. For the day shift they are lighted off at 11.00 P.M., charging begins at 2.00 A.M. and the wind goes on at 3.30 A.M. Bottom is dropped about 1.30 P.M. and water turned onto the dump immediately. By 5.00 or 6.00 P.M. the refuse has been removed and the men are chipping out, copious streams of water being used to cool the stack to the point of tolerance. By 9.00 or 10.00 P.M. the daubing is in and the furnace is ready for another cycle. The night furnaces are on the same basis, placing A.M. for P.M. In the special foundry there are two cupolas which run on alternate days, the shifts being about eight or nine hours and no water cooling is necessary. In the specialty shop, one cupola is run every day, but as the heats are only about two hours, it has ample opportunity to cool off before the tender has to go into it. The following figures tell the story:

Cupolas	Cooling	Life of lining	No. hours heat per lining
Pipe Foundry	Artificial	Six Months	1500
Special Foundry	Natural	Twelve Months	1300
Specialty Shop	Natural	Twelve Months	600

The only explanation of this that occurs to the writer is that the pipe foundry cupolas never really get cold except over Sunday and they consequently do not suffer as much contraction between heats. The reason for the poor showing of the specialty cupola is that so much of its heat is blowing out which, as explained above, is particularly hard on the lining. The special foundry operates on higher temperatures than the others, which may explain the slight difference there, but it would not seem to make up for the water treatment.

The Stock

The cupola charge consists of fuel, flux and metal in the general proportions of about 12 fuel and 2 flux to 100 parts of metal. The properties of any one may greatly affect the proportions above and the temperature requirements of the foundry are the prime consideration in fixing the coke, but the general average will not be far from that given.

Fuel

Practically the only fuel now used is coke. Formerly, only beehive coke was considered for foundry work but the by-product oven is fast winning its way. There is not much difference between them in the final analysis, for though the beehive is not so readily dissolved (Eq. 2, p. 722), the chances for oxidation are greater. Further, the angular structure of the beehive is against it as is also the fact that the by-product coke is commonly better sized. The effect of one of those huge blocks of strong angular beehive coke sometimes seen charged, with several hundred pounds of iron holding it against the wall in its descent, can readily be imagined. On the other hand there is more chance of getting a lot of "breeze" in the by-product than the beehive. A very hard coke is unduly abrasive and a very soft coke crushes under the burden, so neither extreme is desirable. The relation between structure and combustibility or reactivity has not yet been satisfactorily determined, but in general these properties would seem to diminish as the hardness increases. Therefore, a soft soluble coke would demand a higher fuel consumption than a hard insoluble one with consequently more ash. It might well be that the hard coke, being less reactive than the soft coke, would save the lining more by reducing the slag than the soft coke would by lower abrasion. The reaction (Eq. 2) of carbon and carbon dioxide to the monoxide is a function of the time of contact which depends on the surface exposed, therefore, the smaller the coke the greater the amount lost as monoxide. Small coke should be avoided for this reason as well as for its tendency to pack. The author's experience is that coke of 3 to 5 inches is the most satisfactory and that extreme hardness is neither necessary nor desirable.

The amount and composition of the ash is by far the most important characteristic of the coke, though as explained above, the percentage of ash is not the ultimate consideration, for a coke with 10% ash which allows a melting ratio of 10 to 1 will be better than one with only 9% ash which will permit a ratio of only 8 to 1. The writer is not familiar with any analytical work on the ash contents of the various cokes, but it is apparent that the more iron it contains the greater will be the damage, and that the higher the silica present the more flux will be needed to take care of it with consequently more slag to act on the lining. Assuming that there is no difference in the composition of the different ashes and that the efficiency of the fixed carbon is the same, the flux will increase more rapidly than the ash for each increment of ash demands an equivalent of flux, which requires more coke for melting it, which brings in more ash to be fluxed, etc.

The writer once tried a very fine looking coke with excellent physical properties, but 17% ash. In an experimental cupola on short runs where slagging was not necessary it gave excellent results, but in the regular

operation, where it was necessary to slag, the amount of flux required was so great that it was impossible to melt hot enough for the work with a ratio of only 6 to 1, although the usual ratio with the standard 10% ash coke was about 9 to 1 for this particular foundry. The cutting out of the lining on this heat was terrific. To be sure there was not some other cause of the trouble, the experiment was repeated but the results were identical, though the blast was manipulated through a wide range in the effort to get the iron hot.

Flux

The principal flux in use is limestone though other forms of calcium carbonate, such as oyster shells and marble waste, are used where local conditions are favorable—these latter being particularly desirable on account of their purity. Fluorspar is used sparingly in some cases and is a very quick and valuable means of thinning the slag when it is "sticky" but should be used only as medicine for it is very destructive to the lining.

The role of magnesium is not quite clear. Dr. Moldenke says it is "an excellent fluxing material" and Johnson ("Principles, Operation and Products of the Blast Furnace") cites an instance of very fine results from its use in a blast furnace making basic pig iron. Field, however (Bureau of Mines, Technical Paper 157), shows a pronounced increase in the viscosity of a synthetic slag by substituting 20% MgO for 20% CaO. Field and Royster in a later paper (Bureau of Mines, Technical Paper 187) show the lowest viscosity of actual blast furnace slag at 5.5% MgO, the limits investigated being 1.5 to 7.5%. Their conclusion is that "the difference between the two is not caused by the magnesia as such, but by the fact that its presence lowers the percentage of lime relative to alumina and silica. In other words, magnesia and other minor constituents, if present in amounts not exceeding 14%, act as more or less neutral substances and can be left out of consideration." The writer has used limestones varying in magnesia from 1% to 12%, but has never been able to detect any particular effect traceable to this variation. Iron is objectionable but is usually present in very small percentages and is lost in the shuffle.

The most important point to be watched in the flux is the amount of insoluble residue, which is mostly clay and silica. As one pound of sand or clay requires nearly three pounds of calcium carbonate to produce a fluid slag, each per cent of such impurity lessens the amount of available flux by four, this additional slag requires more coke to melt it which adds more ash to be fluxed, etc., *ad nauseam*.

Metal

Probably the most desirable charge that can be imagined is one consisting of iron balls two or three inches in diameter and free from sand and rust. Such a charge would allow of perfect distribution in the cupola,

would give a minimum resistance to the blast, would require only sufficient flux for the ash of the coke, would absorb heat rapidly enough for good melting, and would offer very little surface for oxidation. Such an ideal is of course unattainable, but the effect of the actual condition of any given charge may well be measured by its deviation from such a standard. Thus large and unwieldly pieces, such as sows, rolls of various kinds, and all manner of heavy machinery parts are difficult to place properly in the cupola and are slow to absorb heat. The writer once had some steel balls of about 400 lbs. weight to melt. The first one tried was put in without any special precaution and although the heat lasted some two hours after it was charged, it was found in the drop having lost only about half its weight. After that it was found that by putting some half its weight of extra coke just beneath one we could get it melted very nicely. Even where the section is not heavy, a large piece such as a plate cuts down the area available for the blast, and thus increases its velocity while at the same time depriving the stock above it of the contact with the hot gases necessary for preheating. Large hollow articles such as stoves, pipe, acid eggs and the like, when charged unbroken, not only divert the blast but, when they do finally melt, cause a sudden rearrangement of the whole body of stock above them with consequent danger of disturbing the orderly arrangement of the charges. Long pieces such as rails and arbors often get cocked up against the wall and cause trouble from scaffolding.

Fine scrap such as borings, shot and sweepings have a tendency to run down ahead of their turn through the melting zone and into the high oxygen region near the tuyères where they burn and add more to the slag than to the iron. Where they are already rusted, as they usually are, the trouble is increased. Thin stuff such as stove plate suffers from oxidation, 80% being very good recovery in the ladle—the rest going to iron oxide which is, as before stated, the most damaging constituent of the slag. Light steel scrap is even worse for it has not the carbon of the stove plate to protect it. The writer once ran a heat of 5000 lbs. of tin cans, barrel hoops and hack saw blades, from which he obtained 1800 lbs. of the "wildest" metal he ever witnessed—a recovery of 36%.

Pig iron is cast in three ways: in sand molds, in iron molds laid out as the sand molds with sand runners leading to them, and in the chill molds of a casting machine. The sand cast is covered with sand, but usually of nice size. The chill cast is fairly clean but often the pigs are too large and heavy. The machine cast is free from sand but is often made too heavy, especially for small cupolas. The effect of sand on the pig is of course the same as it is in the coke or stone except that in addition to the increase of flux required it makes the pig more abrasive. It remains then to examine these forms of pig iron from the chemical point of view. The combined carbon is lowest in the sand cast and highest in the machine cast on ac-

count of the more rapid cooling of the iron in the latter case. The combined carbon is what determines the melting point and the total carbon determines the freezing point. As an illustration, consider two pure iron-carbon alloys of 4.3% carbon, one of which has been cooled so slowly that all its carbon is free, or graphitic, and the other cooled so quickly that all its carbon is combined. We have in the first case a mixture of pure iron whose melting point is 1535°C with carbon mechanically enmeshed sufficient to lower its freezing point to 1135°C. In the second case the melting point is 1135°C which is also its freezing point. Of course it is impossible to melt quickly enough to prevent some solution of the graphite by the dead soft matrix of the gray iron but with the large thick flakes of graphite and the large grains of ferrite usually present in the soft irons, the action is probably quite slow until very high temperatures are reached, so that in the case mentioned we might well expect a combined carbon of only 1% or 2% by the time it begins to melt which would, even in the latter case, give us a melting point of about 1350°, or over 200° higher than that of the white iron. Dr. Moldenke (P. I. F., pp. 204) cites an actual test where a difference of 3% combined carbon gave a difference of 120° in the melting point in favor of the gray iron. The influence on the lining comes from the necessity of maintaining the bed of coke at a greater height for the chilled iron so that it will acquire the necessary super-heat for casting after it is melted, whereas the gray iron possesses it as soon as it becomes molten. "Off-grade" irons, which are usually produced

TABLE I

Per cent scrap

	20	25	30	35	40	45	50	60	70	80	90
	150	100	110	65	65	80	150	125	110	35	75
	150	200			50	40	110	40	125	40	115
	175	100			60	80	110	70	75	35	75
	150	180			70	130	80		15	65	45
	130	160			75		110		50	35	30
	175	125			75				60	60	100
	50	100			160				75	45	
	160	110			135				75		
	125	200			75				50		
	135	150									
	140	160									
	185	135									
	150	125									
		130									
Ave.	144	141	110	65	85	82	112	78	65	45	73

Av. % scrap	Heats
20–30	141
35–50	92
60–70	70
80–90	58

when the blast furnace is in trouble, commonly contain dissolved oxides which are not only destructive to the lining but very troublesome in the foundry. They should never make up a large proportion of the charge if good castings are desired.

Much has already been said about scrap, but from the present point of view the writer feels that it is the most important feature of the charge. As stated before, oxidation is undoubtedly the chief cause of its destructiveness especially when using light scrap such as stove plate and "country" steel. The writer used for several months a charge of 50% light to medium steel scrap, 25% stove plate, and 25% agricultural scrap and foundry returns. This was for duplexing in a basic electric furnace and was not required to be very hot, but the volume of slag was enormous, the coke ratio had to be kept at 7 to 1, and the melting zone seldom went ten hours without showing a hot spot. To check up the influence of scrap on the lining the records of the company were carefully gone over and Table I was prepared. These records were only begun in the latter part of 1917, but the period since then includes the very interesting experience of the electric furnace which allowed the use of the high percentages of scrap indicated. The table gives the number of heats per lining listed under the scrap percentage used during its life. There are, of course, inconsistencies but the general trend is striking. Most of the extraordinarily good results on the high scrap mixtures were obtained by relining the melting zone with new blocks. This was not entered in the records as a "lining." With low scrap mixtures this is never done as the abrasion in the stack is what determines the life in this case.

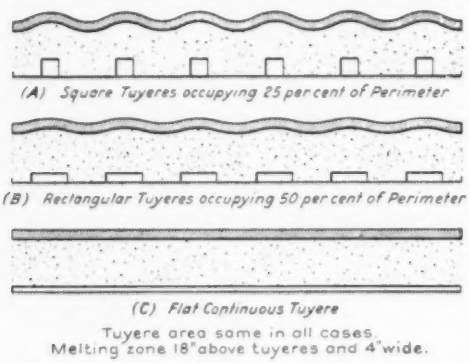
(A) Square Tuyeres occupying 25 per cent of Perimeter
(B) Rectangular Tuyeres occupying 50 per cent of Perimeter
(C) Flat Continuous Tuyere
Tuyere area same in all cases.
Melting zone 18" above tuyeres and 4" wide.

FIG. 1.

Blast

The chief factors to be considered are velocity, temperature and the persistence of oxygen. A great deal in this connection may be attributed to the stock as has already been indicated: large pieces cutting down the area causing a rush of gas through the opening remaining; large coke allowing oxygen to persist throughout the stack (Belden, U. S. Bureau of Mines, Bulletin 54, 14); small coke causing channels; slag being too viscous to run out, thus clogging up the furnace around the tuyères. The fundamental consideration, however, is the size, shape and distribution of the

tuyères. The ideal is a flat tuyère occupying the whole circumference of the furnace. This gives a smooth shaped melting zone of the same height on the walls everywhere and easy to start off with the correct bed. Figure 1 shows roughly the intersection of the melting zone with the walls for three types of tuyères: square ($b = d$), rectangular ($b = 2d$), and the flat tuyère ($b = 4d$) now gradually supplanting these two. It is apparent that with either of the first two a level bed will be either too low for just over the tuyères or unnecessarily high for points between them and it would be impossible to put in a bed of such shape. Upper tuyères cause a weakness in the most important courses of the blocks and add oxygen to the blast at a very troublesome point. They serve no useful purpose, for better results can be obtained by using the correct amount of air through one row, if this is of the proper dimensions.

The correct blast pressure depends on the character of the charge, especially the coke, the height of the stack and the diameter of the cupola. It should be sufficient to drive the blast well into the shaft, otherwise there will be an undue amount passing up against the wall and the interior of the stack column will be worse than useless. Table II shows the

TABLE II

Inside diameter, inches	Pressure, ounces per sq. in.
66	12–14
60	10–12
54	8–10
42	6– 8
18	3– 4

inside diameters of the cupolas used by the writer and the blast pressure found by experiment to give the best results. The attempt was once made during a period of depression to run the 66-inch stacks on 6 ozs. pressure so as to slow them up, but after several "freeze ups" it was abandoned. One experience stands out in particular. The furnace had run cold for several hours and it was decided to drop it without waiting to blow out. A column of slag, coke and iron of about three feet in diameter was dropped out, that was evidently the first iron charged. It had simply lain in the middle of the cupola and fused enough to sinter it together but there it stayed until the bottom was dropped. Half pigs had melted off and left the other half stuck in the mass.

Far more damage is done to linings and castings by too much blast than by not enough—the natural tendency being to "crowd 'er" and get the heat off as quickly as possible. Chief among high pressure troubles are oxidation of the iron with corresponding increase in the volume and corrosiveness of the slag; bridging or scaffolding at and just over the tuyères from chilled slag and iron; and a tremendous increase in the abra-

sive effect of particles of sand, slag and coke which are blown up the walls like a sand blast. The effects of oxidation are seen in the shortened life of the molten metal and in honeycombed castings. The slag becomes "foamy," often contains considerable iron shot and solidifies to a porous mass of a dull black or brown color in striking contrast to the dense, vitreous structure of good slag with its glossy, dark green color. Accidental stoppage of part of the tuyère area by a "drop out" of the daubing frequently causes the phenomenon even under the best conditions and, unless the tuyères can be opened up, the destruction of the lining is very severe. In fact, one such off heat will cause more damage to a lining than weeks of normal operation.

Furnaces running on high pressure are particularly liable to bridge. The trouble starts by particles of slag freezing as they trickle through the cold blast catching coke and iron to form a dense mass that obstructs the wind and gives it increased velocity through the remaining space. The effect is cumulative and may even go to complete stoppage of the blast. A poor daubing material will often cause trouble by melting off early in the heat and freezing over the tuyères and the same may be said of cheap brick used for patching or lining. Not the least trouble from a bridge is the damage to the lining caused by removing it. Frequently sledge hammers are necessary for this work and the brickwork is severely jarred with consequent danger of cracks.

Little can be said of the blast temperature as it is obviously dependent on the proportion of iron to coke and on the character of the coke. With a very pure, highly reactive coke good nine-inch blocks can easily be melted through in a few hours as the writer has personally seen when using pitch coke in excess. Iron was actually tapped at 1600°C in one experiment with this coke which would probably mean at least 1800°C somewhere in the cupola, if not more. No refractory could be expected to stand such temperatures under the conditions of actual operation. Where excessive temperatures are required for the work, the life of the linings will inevitably be short, but linings are cheaper than rejected castings.

In conclusion, it may be said that in one point only does good foundry practice work against the lining and that is high temperature. As the normal working of the cupola gives hot iron, cold iron is a sure sign that something is wrong. It is far better to melt hot and cool with scrap than to court disaster by melting cold. Really, in the last analysis, it is doubtful whether correct melting will attack the lining any faster than cold melting on account of the increased chances of oxidation in the latter. In all other respects the interests of the foundry and of the liner are identical. The remarks given in this paper concerning methods of lining, daubing, lighting and charging; the remarks about tuyères and blast pressure; and the remarks about fuel, flux and the character of metal would apply

just as well in a paper on foundry practice as they do here. Iron oxide has been discussed at length, as to its effect on the linings, but its effect in the foundry is much more important and costly. It would not be too much to say that the finest thing that could be done would be the elimination of oxidation in the cupola, the price of which is vigilant application of the fundamental principles and painstaking attention to the humdrum of every-day routine.

METALLURGIST, AMERICAN CAST IRON PIPE CO.
BIRMINGHAM, ALA.

Discussion

G. A. BOLE: We should know more accurately the service conditions that exist in a cupola in order to be able to prescribe more surely a refractory for the various areas. Some years ago the Bureau of Mines attempted studies of the temperature distribution and the atmosphere in the cupola. They had a great deal of trouble, however, in getting data, especially on the temperature due principally to the descending charger. They placed thermocouples at various depths in the charge and at various heights above the tuyères. They also took gas samples at the same places. This work is reported by A. W. Belden.[1]

W. G. GRIFFITH: We find that one very large foundry in the country wishes a brick as dense as it can possibly be made and they are able to get reasonable refractory values from that sort of brick.

There is another foundry that consumes an immense amount of material that insists on a blast furnace quality brick throughout and they will listen to nothing else.

That is obviously a grave mistake and a little getting together on this point would result in better foundry refractory material. As it is well known, the refractory manufacturer is usually limited in his choice of raw materials to plastic and flint clay. To secure the greatest refractory value from his material enjoins the use of the greatest quantity of flint clay consistent with the necessary strength in structure of the material which he is producing. This is so because ordinarily the plastic clays have a considerably lower refractory value than the flints. If the manufacturer is confronted with a situation where he is required to produce material to resist high heats and at the same time provide an extremely tough material, he ordinarily meets the emergency by reducing the more refractory raw material and strengthening the structure with the plastic, or less refractory material. He goes as far in this direction as he thinks it is safe, and tries to make the adjustment with as little sacrifice as possible in either direction, that is, toward the reduction of the refractory value and the sacrifice of density. It is very plain that if the manufacturer was not required

[1] U. S. Bur. Mines, *Bull.* **54.**

to combine two inharmonious qualities in the same brick, he could meet the situation much better.

If he were allowed to make a hot zone brick of his best material, having in mind only the conditions that obtained in this zone, and if on the other hand, he were permitted to make an extremely dense brick from his plastic clay to meet the conditions which obtain higher up in the cupola and if these two different materials, each suited to its own place, were used, I believe that a great deal of this complaint would be obviated. I fully realize that carrying two stocks of material, and the possibility of confusion would be an inconvenience, but as it is made plain by this discussion that a serious problem exists, I believe that this inconvenience is the proper burden of the consumer, and, until he has made this proper effort he should not lay all of his woes on the back of the manufacturer. The manufacturer will be glad to work with the consumer and will take an interest and pride in the production of better cupola linings if he can secure the coöperation of his customer. Of course, this coöperation is sometimes secured, but from my experience, it is not general by any means.

L. C. HEWITT: There are a number of conditions that seem to affect the life of cupola blocks, such factors as: size of cupola, rate of melting in proportion to size, that is, pounds per square inch of area per hour, time taken for total melt, total tons melted, makeup of charge whether iron or steel, fluxes used and quantity, height of coke beds, quality of coke, ratio of coke to iron, blast pressure and tuyère ratio to cupola area.

In this case, of course, we are comparing in a sense one cupola against another, whereas, Mr. MacKenzie's paper, I believe, deals particularly with the conditions that might affect the refractory life in any one cupola.

EFFECTS OF COMPOSITION ON THE PROPERTIES OF SHEET STEEL ENAMELS[1]

By H. G. Wolfram and W. N. Harrison

ABSTRACT

The effects produced by the substitution of feldspar for flint and flint for feldspar together with variations in other constituents commonly used in enamels were studied with reference to their resistance to mechanical shock, thermal shock and acid attack. Tests were made on three series of enamels of twenty each which were applied to 8-inch steel dinner plates over a standard ground coat. The enamels of the series containing both flint and feldspar were found to be most satisfactory for general use. Results indicate that enamels having certain excellent properties, making them more suitable for special purposes, may be found in the other two series.

Introduction

Investigations of the properties of enamels for sheet steel as affected by changes in composition have been largely confined to (1) methods of testing, (2) the cause and remedy of some particular defect, or (3) the effects of substituting some one ingredient for another. Manufacturers, anxious to apply the results obtained, are handicapped by the relatively small number of available enamels of satisfactory properties. The need for more information was considered sufficiently urgent by the Bureau of Standards to justify determination (1) of the effects produced by greater changes in composition than have heretofore been attempted and (2) whether the present limited number of enamels could be increased.

Plan of Investigation

Three series of enamels were studied. Series I, in which the refractory[2] portion consisted entirely of feldspar, represents one extreme. Some manufacturers substitute feldspar for flint to increase the coefficient of expansion to equal nearly that of the metal bases without materially altering the refractoriness of the enamel. Series II presents more closely the commercial enamel containing feldspar and flint in the ratio of 7:5. Series III, the other extreme, has flint only as the refractory portion. This, of course, should produce a decrease in coefficient of expansion. Because the composition of commercial feldspars varies whereas flint is more uniform, replacement of all feldspar by flint might insure more uniform results.

In each series various fluxes and opacifiers were substituted systematically one for another.

The enamels were applied to 8-inch steel dinner plates; tested for resistance to thermal shock and acid attack; examined for relative opacity

[1] Published by permission of the Director of the Bureau of Standards of the U. S Department of Commerce. Recd. Sept. 11, 1925.

[2] See H. F. Staley, Bur. Stand., *Tech. Paper* **142**, pp. 7–28.

TABLE I

BATCH WEIGHTS

(Parts of the whole)

Enamel No.	Feldspar[1] and flint	Borax	Boric acid	Sodium nitrate	Soda ash	Cryolite	Fluorspar	Sodium antimonate	Zinc
1	60	40.9	..	4.8	11.3	10	..	..	..
2	60	40.9	..	4.8	11.3	..	10	..	..
3	60	40.9	..	4.8	11.3	..	..	10	..
4	60	40.9	..	4.8	11.3	..	..	..	10
5	60	20.0	14.8	4.8	..	10	10	..	..
6	60	20.0	14.8	4.8	..	10	..	10	..
7	60	20.0	14.8	4.8	..	10	..	..	10
8	60	20.0	14.8	4.8	..	..	10	10	..
9	60	20.0	14.8	4.8	..	..	10	..	10
10	60	20.0	14.8	4.8	..	..	..	10	10
11	60	13.62	..	4.8	18.8	10	10	..	..
12	60	13.62	..	4.8	18.8	10	..	10	..
13	60	13.62	..	4.8	18.8	10	..	..	10
14	60	13.62	..	4.8	18.8	..	10	10	..
15	60	13.62	..	4.8	18.8	..	10	..	10
16	60	13.62	..	4.8	18.8	..	..	10	10
17	60	13.62	..	4.8	1.72	10	10	10	..
18	60	13.62	..	4.8	1.72	10	10	..	10
19	60	13.62	..	4.8	1.72	10	..	10	10
20	60	13.62	..	4.8	1.72	..	10	10	10

TABLE II

COMPOSITIONS MELTED, CALCULATED CUBICAL EXPANSIVITY AND RESULTS OF TESTS

	Variable Constituents (% of total)						Series I[2] Ratings					
Enamel No.	Boric oxide (B_2O_3)	Sodium oxide (Na_2O)	Cryolite (Na_3AlF_6)	Fluorspar (CaF_2)	Sodium antimonate ($NaSbO_3$)	Zinc oxide (ZnO)	Cubical coeff. expansion ($\times 10^{-7}$)	Thermal test (units)	Acid test (units)	Opacity (units)	Impact on edge (ft.-lbs.)	Impact on center (ft.-lbs.)
1	10	10	10	..	..	..	388	11	19	2	0.245	0.325
2	10	10	..	10	..	..	339	11	15	1	.179	.313
3	10	10	..	..	10	..	360	11	43	9	.183	.275
4	10	10	..	..	..	10	332	2	21	8	.177	.312
5	10	..	10	10	..	..	313	8	36	2	.154	.300
6	10	..	10	..	10	..	334	7	51	4	.145	.338
7	10	..	10	..	..	10	306	3	12	9	.150	.281
8	10	..	..	10	10	..	285	13	27	10	.173	.331
9	10	..	..	10	..	10	257	11	22	5	.192	.306

[1] Series I contains 60 parts feldspar, no flint.
Series II contains 35 parts feldspar and 25 parts flint.
Series III contains 60 parts flint, no feldspar.

[2] Constant portion 60% feldspar, 5% sodium oxide and 5% boric oxide, no flint.

10	10	..	..	..	10	10	278	15	30	3	.150	.275
11	..	10	10	10	..	..	412	1	31	4	.276	.256
12	..	10	10	..	10	..	433	1	28	1	.176	.310
13	..	10	10	..	..	10	405	1	28	3	.292	.344
14	..	10	..	10	10	..	384	1	35	9	.253	.275
15	..	10	..	10	..	10	356	11	56	1	.181	.300
16	..	10	..	..	10	10	377	15	30	8	.216	.481
17	..	..	10	10	10	..	358	1	49	10	.230	.250
18	..	..	10	10	..	10	330	5	18	3	.232	.335
19	..	..	10	..	10	10	351	13	20	8	.167	.381
20	..	..	..	10	10	10	302	13	23	3	.167	.275

Series II[1]						Series III[2]					
	Ratings						Ratings				
Cubical coeff. expansion ($\times 10^{-7}$)	Thermal test (units)	Acid test (units)	Opacity (units)	Impact on edge (ft.-lbs.)	Impact on center (ft.-lbs.)	Cubical coeff. expansion ($\times 10^{-7}$)	Thermal test (units)	Acid test (units)	Opacity (units)	Impact on edge (ft.-lbs.)	Impact on center (ft.-lbs.)
340	6	43	2	0.184	0.362	273	13	60	9	0.188	0.306
291	12	51	1	.161	.337	224	13	60	5	.209	.425
312	12	60	9	.164	.325	245	14	60	5	.202	.406
284	12	42	8	.178	.343	217	15	60	4	.180	.325
265	11	51	2	.161	.387	198	15	60	4	.173	.450
286	11	51	4	.177	.456	220	15	60	5	.169	.400
258	8	42	9	.185	.450	191	14	60	6	.178	.394
237	13	60	10	.198	.475	171	15	60	2	.194	.381
209	14	60	5	.208	.500	143	11	60	1	.172	.387
230	15	60	3	.181	.325	164	15	60	2	.184	.319
364	7	50	4	.255	.337	298	12	60	3	.169	.344
385	1	60	1	.167	.331	319	11	60	4	.184	.356
357	1	51	3	.185	.331	291	13	60	6	.168	.294
336	11	60	9	.161	.325	270	13	60	1	.173	.256
308	7	60	1	.183	.387	242	11	60	5	.177	.376
329	12	54	8	.181	.331	263	14	60	1	.169	.375
310	9	60	10	.175	.356	244	15	60	6	.181	.331
282	11	47	3	.186	.393	216	15	60	4	.191	.400
303	11	45	8	.175	.331	237	15	60	5	.175	.306
254	15	60	3	.166	.387	188	14	60	2	.175	.306

and subjected to impact tests. The results of these tests are correlated with the enamel compositions.

The compositions of the frit, as calculated, consisted in all cases of 60% feldspar, or flint, or both and at least 5% each of boric and sodium oxides.

[1] Constant portion 35% feldspar, 25% flint, 5% sodium oxide and 5% boric oxide.

[2] Constant portion 60% flint, 5% sodium oxide and 5% boric oxide, no feldspar.

The remaining 30% was made up of equal percentages of three of the following commonly used constituents: boric oxide, sodium oxide, cryolite, fluorspar, sodium antimonate and zinc oxide. All possible combinations of any three of these materials were employed with each of the different refractory portions. This gave a total of 60 enamels. The batch compositions are given in Table I and the compositions of the frits are included in Table II.

Preparation

Small batches of the enamels were first prepared to observe their working properties; after this, batches of approximately 30 pounds each were smelted in a rotary smelting furnace (to simulate more nearly plant conditions) and prepared for application. The enamels were applied over a standard ground coat by dipping, and fired for $1^1/_2$ to $2^1/_2$ minutes at 850° to 875°C (1562° to 1607°F) in a gas-fired muffle having a chamber 20 x 48 inches and 8 inches to the spring of the arch. The standard ground coat used was:

GROUND COAT 420

Frit (batch composition)		Frit (computed composition after melting)		Mill batch	
Borax	33.3%	Feldspar	30.90%	Frit	100.0 lbs.
Feldspar	23.8	Clay	4.45	Clay	7.0 lbs.
Flint	21.9	SiO_2	28.40	Borax (Sol.)	1.5 lbs.
Soda nitrate	7.1	Na_2O	10.40	Water	50.0
Potassium nitrate	4.3	K_2O	2.60		
Fluorspar	4.2	B_2O_3	15.84		
Clay	3.9	CaF_2	5.45		
Cobalt oxide	0.4	CO_3O_4	0.52		
Manganese oxide	.7	MnO_2	.84		
Nickel oxide	.4	Ni_2O_3	.60		
	100.0		100.00		

Methods of Test

Thermal Shock

Resistance to thermal shock was tested by placing a plate containing 25 cc. of water on a small gas stove of the ordinary star burner type, the height of the flame being controlled by a constant gas pressure. After boiling to dryness, the plate was allowed to remain over the flame for 15 seconds, and then, while still over the flame, 25 cc. of water at room temperature was poured rapidly into it. This procedure was repeated ten consecutive times unless failure resulted sooner. A chip 0.25 inch or more in diameter was considered as indicating a failure and each piece of ware which failed on or before the tenth treatment was given a rating number corresponding to the number of treatments required to produce failure.

It was found upon examining the results of these tests, that ratings could

be given to those plates which withstood the ten tests, on the basis of defects not serious enough to be classed as failure. These plates were given ratings from eleven to fifteen, the highest indicating the complete absence of defects. This test is very severe, necessarily so to insure failure of a majority of the pieces within a reasonable number of treatments.

Impact Tests The impact tests employed in this work are the same as those used by Danielson and Sweely.[1] The apparatus is essentially a pendulum with a hammer of a definite mass (6 oz.). The kinetic energy (in ft.-lbs.) of this hammer at the instant of striking is taken as a measure of the severity of the blow. The kinetic energy of each succeeding blow is increased by equal increments, making the blows progressively more severe, until the test piece fails.

The results are directly comparable only when specimens and apparatus are of the same size, shape and mass and with the same increments of kinetic energy of the hammer blows. The plates were tested for resistance to impact at the center of the bottom and on the curved surface, the outside of the plate being struck by the hammer. In both cases the blow was normal to the surface at the point of impact. In these, as in the thermal tests, a chip 0.25 inch in diameter was considered as indicating a failure. Two hundred and forty plates representing the sixty enamels, were tested at the center and at four equidistant points on the curved surface. The average of the energies required to produce failure in the respective tests represents the rating of each enamel.

Opacity[2] The relative opacity of the enamels was estimated by visual comparison by two independent observers who examined four sample plates of each enamel in order to minimize the effect of any accidental differences in apparent opacity. The differences in the ratings resulting from the comparisons by the two observers were small. There being a sufficient range of opacity to warrant such a division, the 60 enamels were divided into ten groups of six each and rated from one to ten, the highest number representing the greatest opacity. A good commercial enamel, tested under these same conditions, was rated at seven.

Resistance to Acid The method used for testing enamels for resistance to acid has been previously described[3]

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[1] R. R. Danielson and B. T. Sweely, "The Relations between Composition and Properties of Enamels for Sheet Steel," *Jour. Amer. Ceram. Soc.*, **6** [10], 1011–29 (1923).

[2] A number of tests of these enamels with the Pfund colorimeter indicated that considerable time would be necessary to develop a satisfactory method of determining opacity with this instrument. It was, therefore, not used to obtain the ratings given in this paper. The instrument is described by A. H. Pfund, "The Colorimetry of Nearly White Surfaces," *J. Franklin Inst.*, **189**, 371 (1920).

[3] "Relations between Composition and Properties of Enamels for Sheet Steel," *loc. cit.*

and depends on the action of 1% acetic acid solution on the enamel at room temperature, for ten consecutive, five-minute periods. The plate to be tested was tilted at an angle of about 8° and enough acid solution poured in to cover half the bottom of the plate. After five minutes, the acid was removed, the plate rinsed, dried thoroughly and examined. This test was repeated ten times, and the extent of the attack observed after each acid treatment and rated as follows: 6—no visible effect; 5—very slight loss of gloss; 4—slight loss of gloss; 3—complete loss of gloss; 2—slight etching; and 1—decided etching. The sum of the ratings for each of the ten 5-minute periods was the final rating of the enamel. An enamel having a rating of 60 showed no visible attack upon completion of this series of tests, while one having a rating of 10 was considerably etched.

Results

General

The results of the tests are in Table II. This table also includes the calculated coefficients of cubical expansion, and the compositions of the frit, showing the systematic scheme for the introduction of the variable constituents. This arrangement facilitates a correlation of the results with the compositions of the frit. The coefficients of expansion of the enamels were calculated from the computed composition of the frit according to the values assigned to the various oxides and compounds by Mayer and Havas.[1] No actual coefficients were determined, but the calculated values, although at best only approximate, give important relative data.

In order to simplify the comparison of the rating of an enamel in one test with its rating in another and to make a comparison of the rating of one enamel with that of another in the same test easier, the data in Table II were reduced to a common basis and are presented in Table III. In this table a rating of 10 indicates the highest standing and a rating of 1 the lowest, all the results on the 60 enamels being taken into account. By the aid of this table one or more enamels can be readily selected as the most desirable of the series for a given purpose or use. Such a choice will depend on the qualities desired. For example, in the application of enamels to shaped ware requiring a cover coat on both sides, a low coefficient of expansion may largely be disregarded as a source of warpage,[2] while in the manufacture of flat ware a consideration of the expansivity is extremely important. Similarly enamels for kitchen ware should be

[1] Mayer and Havas, *Sprechsaal*, **42,** 497; **44,** 188, 207 and 220. (A list of values for the oxides ordinarily used in enamels is given in "Enamels," by R. D. Landrum and published by Harshaw, Fuller & Goodwin Co. A partial list is also given in Bur. Stand., *Tech. Paper* **142.**)

[2] "Factors Affecting the Warpage of Sheet Iron and Steel in Enameling," Danielson, Hartshorn and Harrison, *Jour. Amer. Ceram. Soc.*, **7** [5], 326–40 (1924).

resistant to acid and thermal shock while those qualities may largely be sacrificed for better opacity and resistance to mechanical shock in enamels for flat ware. Enamels which are troublesome to smelt or which produce ware of poor appearance must be avoided in any case.

Considering these qualities with reference to Table III, enamel II-9 might well be selected as the most desirable for shaped ware because: (*a*) as a whole, the results of the tests are higher than for any other of the 60 enamels, (*b*) it is not troublesome to smelt, (*c*) its low coefficient of expansion is not liable to cause any considerable warpage in this type of ware. The slight tendency to crawl which is indicated in the table is hardly enough to overbalance the good qualities and it could probably be overcome.

II-6 shows higher expansivity, no tendency to crawl and a better opacity, at the expense of some mechanical strength, acid resistance and ease of smelting, and might be preferred to II-9.

For flatware, enamels II-1, II-13 and I-14 seem promising because:

TABLE III

PHYSICAL PROPERTIES AND NUMERICAL RATINGS

Series I

Enamel No.	Time smelting, min.	Remarks		Cubical coefficient of expansion $\times 10^{-7}$, Calculated	Relative rating in different tests. Best rating is 10				
		Nature of melt	Finished ware		Thermal test	Acid resistance	Opacity	Impact on edge	Impact on center
1	50	Fluid	Fish scale	388	7	2	2	7	4
2	50	Fluid	Fish scale	339	7	2	1	3	3
3	120	Viscous, frothy	Matt	360	7	7	9	3	2
4	90	Viscous, frothy	Matt	332	1	3	8	3	3
5	60	Very viscous	O. K.	313	5	6	2	1	3
6	65	Slightly viscous	O. K.	334	5	9	4	1	4
7	45	Fairly fluid	O. K.	306	2	1	9	1	2
8	75	Slightly viscous	O. K.	285	9	4	10	2	4
9	60	Slightly viscous	Crazed and chipped	257	7	3	5	4	3
10	120	Very frothy, viscous	O. K.	278	10	5	3	1	2
11	50	Fairly fluid	O. K.	412	1	5	4	9	1
12	90	Slightly viscous	O. K.	433	1	4	1	3	3
13	60	Fairly fluid	Crazed	405	1	4	3	10	4
14	60	Fluid	O. K.	384	1	6	9	8	2
15	45	Very fluid	O. K.	356	7	10	1	3	3
16	70	Very frothy, viscous	Matt	377	10	5	8	5	10
17	45	Slightly viscous	O. K.	358	1	8	10	6	1
18	40	Slightly viscous	O. K.	330	3	2	3	6	4
19	60	Fluid	Slight crawl	351	9	3	8	2	6
20	75	Viscous	Poor gloss	302	9	3	3	2	2

TABLE III (*Continued*)

Enamel No.	Time smelting, min.	Remarks: Nature of melt	Remarks: Finished ware	Cubical coefficient of expansion $\times 10^{-7}$. Calculated	Relative rating in different tests. Best rating is 10: Thermal test	Acid resistance	Opacity	Impact on edge	Impact on center
			Series II						
1	45	Fluid	O. K.	340	4	7	9	3	5
2	45	Fluid	O. K.	291	8	9	6	2	4
3	55	Slightly viscous	O. K.	312	8	10	7	2	4
4	45	Fluid	O. K.	284	8	7	8	3	4
5	40	Fluid	O. K.	265	7	9	9	2	6
6	55	Viscous	O. K.	286	7	9	10	3	9
7	45	Fluid	Tendency to crawl	258	5	7	10	3	9
8	75	Very viscous	Some tendency to crawl	237	9	10	6	4	10
9	40	Fluid	Some tendency to crawl	209	9	10	7	5	10
10	50	Fluid	Tendency to crawl	230	10	10	6	3	4
11	45	Fluid	O. K.	364	5	9	2	8	4
12	45	Fluid	O. K.	385	1	10	8	2	4
13	50	Fluid	O. K.	357	1	9	7	3	4
14	55	Fluid	O. K.	336	7	10	8	2	4
15	55	Fluid	O. K.	308	5	10	7	3	6
16	80	Very viscous	Matt	329	8	9	7	3	4
17	60	Viscous	O. K.	310	6	10	10	3	5
18	30	Fluid	O. K.	282	7	8	3	3	6
19	60	Fluid	O. K.	303	7	8	10	3	4
20	60	Viscous	O. K.	254	10	10	7	2	6
			Series III						
1	40	Fluid	O. K.	273	9	10	9	3	3
2	45	Fluid	O. K.	224	9	10	5	5	8
3	65	Fairly fluid	Slight crawling	245	9	10	5	4	7
4	40	Fluid	Slight crawling	217	10	10	4	3	4
5	55	Fairly fluid	Crawling	198	10	10	4	2	9
6	65	Fairly fluid	Slight crawling	220	10	10	5	2	7
7	55	Fairly fluid	Slight crawling	191	9	10	6	3	6
8	90	Refractory, viscous, frothy	Crawling	171	10	10	2	4	6
9	55	Fluid	Bad crawling	143	7	10	1	2	6
10	75	Viscous, refractory	Bad crawling	164	10	10	2	3	3

11	50	Fluid	Fish scale	298	8	10	3	2	4
12	50	Fluid	O. K.	319	7	10	4	3	5
13	45	Fluid	O. K.	291	9	10	6	2	2
14	55	Fluid	Slight fish scale	270	9	10	1	2	1
15	55	Fluid	Slight fish scale	242	7	10	5	3	6
16	55	Fluid	O. K.	263	9	10	1	2	6
17	120	Very refractory, viscous	O. K.	244	10	10	6	3	4
18	90	Very refractory, viscous	O. K.	216	10	10	4	4	7
19	110	Very refractory, viscous	O. K.	237	10	10	5	3	9
20	160	Very refractory, viscous	Crawling	188	9	10	2	3	3

(*a*) their higher expansivities would be less conducive to warpage, (*b*) they are not troublesome to smelt, (*c*) they do not produce visibly defective ware, (*d*) their opacities are good, and (*e*) their mechanical strength, as is evident from their resistance to both types of impact, is reasonably high.

Although, for minimum warpage, it would be desirable to use enamels having expansivities approaching that of sheet metal, the data in Table III indicate that this requirement cannot be filled beyond a moderate degree without sacrifice of other desirable properties.

Expansivity vs. Resistance to Mechanical and Thermal Shock

Certain relations between the expansivities and the resistance of the enamels to thermal and mechanical shock are suggested by the data in Table IV. The values in this table were obtained by arranging the enamels of each series, together with their respective thermal and impact ratings, in the order of decreasing coefficients of expansion, and taking the averages of the ten highest and

TABLE IV

AVERAGES OF EXPANSIVITY AND RESULTS

Series	Enamels	Average expansivity, cubical ($\times 10^{-7}$)	Average numerical ratings		
			Thermal test	Impact on edge	Impact on center
	First 10	382	6.6	0.222	0.320
I	Second 10	308	8.8	.172	.307
	Average	345	7.7	.197	.313
	First 10	334	7.7	.183	.342
II	Second 10	260	12.2	.180	.405
	Average	297	9.9	.182	.373
	First 10	268	13.1	.179	.350
III	Second 10	193	14.2	.183	.379
	Average	230	13.6	.181	.364

ten lowest coefficients of expansion and of the corresponding numerical ratings for each test. A comparison of these averages indicates that the resistance to the thermal treatment increased with decreased expansivity

throughout the three series. (See Table IV.) That this should be true is apparent from the following considerations:

1. Enamel of high coefficient of expansion.—Consider a plate coated with an enamel of relatively high coefficient of expansion, a cross-section of which is represented graphically in Fig. 1. If the expansivity of the enamel is not quite as great as that of the steel, the enamel will be under slight compression (see $A'A'$, Fig. 1*a*). As heat is applied to the bottom of the plate, the layer (L) of enamel will increase in temperature faster than the steel (S) and the compressive stress will be thereby somewhat increased (see A', Fig. 1*b*). On the top side of the plate, the enamel (U) will increase in temperature more slowly than the steel and the compressive stress already existing there will tend to be relieved (see A', Fig. 1*b*).

After the water has boiled out, and the plate has remained dry over the flame for 15 seconds, the temperature throughout the thickness of the plate will tend to become equalized. When cold water is poured onto the

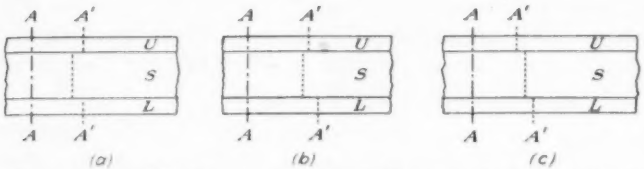

FIG. 1.—Graphical representation of effects produced in enamels of relatively high expansivity, during thermal test. (AA is base or reference line and distance between AA and $A'A'$ represents free lengths, in unstressed state.)

surface, the top layer of enamel cools and contracts very suddenly, and much more rapidly than the steel, as illustrated (see $A'A'$, Fig. 1*c*). The slight compressive stress existing is, therefore, quickly replaced by severe tensile stress and the enamel should soon yield to this treatment by cracking and separating from the metal since its tensile strength is probably very much less than its compressive strength.

It is reasonable to assume that the strength of an enamel in compression greatly exceeds its strength in tension since enamels are not very different from glasses. Winklemann and Schott[1] in an investigation of 17 different types of glass found that their strength in compression exceeded their strength in tension by 9 to 18 times. Danielson and Sweely[2] found the compressive strengths of eight different enamels ranged between 80,500 and 100,700 pounds per square inch, which compare very favorably with

[1] Winklemann and Schott, "Properties of Glasses," *Ann. d. Phys. und Chem.*, **51**, 697 (1894).

[2] "Relations between Composition and Properties of Enamels for Sheet Steel," *loc. cit.*

the values for compressive strengths of glasses as found by Winklemann and Schott.

2. *Enamel of low coefficient of expansion.*—An enamel having a coefficient of expansion much lower than that of the steel will be under considerable compressive stress (Fig. 2*a*) and as the heat is applied that stress will be increased on the bottom layer of enamel (Fig. 2*b*). Its low expansivity, however, keeps that increase from becoming excessive, and its compressive strength is quite sufficient to withstand the increased stress. The steel, increasing in temperature more rapidly than the top layer of enamel, tends to relieve some of the compressive stress already existing there, but these stresses are partially restored in the 15 seconds of dry heat treatment which follows. As the plate is quenched with cold water, the top layer of enamel cools suddenly and much more rapidly than the steel as in the case of the enamel of high expansivity (Fig. 2*c*), but for two reasons, both due to low expansivity of the enamel, the shock is much

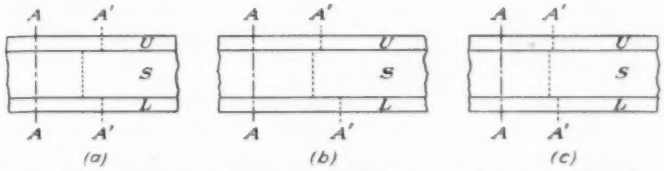

FIG. 2.—Graphical representation of effects produced in enamels of relatively low expansivity, during thermal test. (AA is base or reference line and distance between AA and $A'A'$ represents free lengths, in unstressed state.)

less severe. First, the low coefficient of expansion of the enamel tends to keep its rate of contraction down to that of the metal base. Second, if the rate of contraction of the enamel exceeds that of the steel, in spite of the retardation just mentioned, the compressive stress already existing in the enamel must be overcome before any tensile stress can be exerted. Hence, an enamel of low expansivity might stand this test better than one of high expansivity even though the actual tensile strength of the first mentioned were the smaller of the two.

It would appear from this explanation that the ideal condition for resistance to this treatment would require a low coefficient of expansion for the finish coat and a slight increase in expansivity by steps through the first cover and ground coat, all being lower than that of the steel. This is in harmony with the findings of Danielson and Sweely[1] that for high resistance to failure in the thermal test the expansivity of the ground coat should equal or exceed that of the cover.

[1] "The Relations between Composition and Properties of Enamels," *loc. cit.*

3. Impact test.—That there are certain sources of possible error in the impact tests, and that the actual mechanical strengths of the enamels have effects independent of their expansivities, may account for the fact that the relations between expansivities and resistance to impact are not entirely consistent. Nevertheless, the data in Table IV indicate that resistance to impact on the curved edge of the plate increases with expansivity and vice versa at the center.

That an increase in expansivity should have a different effect for the two different areas subjected to the mechanical shock seems natural when the character of the stresses causing failure is considered. When the blow is on the edge, the curvature of the metal serves as a support and, by tending to lessen the deflection of the surface when struck, prevents excessive tensile stresses from being set up in the enamel opposite the hammer. This rigidity, however, tends to increase the intensity of the force of the blow and, therefore, the layer of enamel next to the hammer is subjected to relatively high compressive stresses. An enamel of low expansivity is already under much greater compressive stress than one of high expansivity and, therefore, less additional stress created by the blow is necessary to cause failure.

In the case of impact on the center, the flat surface is free to deflect, due to the length of span between edges. Compressive stresses are set up in the enamel next to the hammer and over a wide area, due to the deflection of the plate. This deflection, however, causes tensile stresses to be set up on the opposite side of the plate and the fracture occurs on that side in accordance with the assumption that the tensile strength of an enamel is less than its compressive strength. Here low expansivity favors resistance of the enamel to failure because the compressive stress must be overcome before tensile stress can be exerted.

Effects of Ingredients upon Results

The manner in which the results shown in Table II were obtained has already been fully explained. These are rearranged in Table V to show the effects of the variable constituents on the properties of the enamels as indicated by the ratings in the various tests. Since there are six variables and only three are used in each enamel, a comparison may be made by selecting groups of enamels having two of the variable constituents in common and differing from each other only in a single constituent. For example, let us assign arbitrary letters to the various materials used, as follows: *A*, boric oxide, *B*, sodium oxide, *C*, cryolite, *D*, fluorspar, *E*, sodium antimonate and *F*, zinc oxide. The first enamel then would contain in the variable portion *A*, *B* and *C* the second *A*, *B* and *D;* the third, *A*, *B* and *E;* and the fourth, *A*, *B* and *F*. We find that four enamels differ in composition from one another in one constituent only and thus the changes in properties can be compared with

TABLE V

RESULTS WITH CHANGES IN COMPOSITION

Series I

Type	Variables common to type enamel	Thermal Test (A) B_2O_3	(B) Na_2O	(C) Na_3AlF_6	(D) CaF_2	(E) $NaSbO_3$	(F) ZnO	Acid Test (A) B_2O_3	(B) Na_2O	(C) Na_3AlF_6	(D) CaF_2	(E) $NaSbO_3$	(F) ZnO	Opacity B_2O_3	Na_2O	Na_3AlF_6	CaF_2	$NaSbO_3$	ZnO
AB	B_2O_3—Na_2O	..	..	11	11	11	2	..	..	19	15	43	21	..	..	2	1	9	8
AC	B_2O_3—Na_3AlF_6	..	11	..	8	7	3	..	19	..	36	51	12	..	2	..	2	4	9
AD	B_2O_3—CaF_2	..	11	8	..	3	11	..	15	36	..	27	22	..	1	2	..	10	5
AE	B_2O_3—$NaSbO_3$	..	11	7	13	..	15	..	43	51	27	..	30	..	9	4	10	..	3
AF	B_2O_3—ZnO	..	2	3	11	15	..	..	21	12	22	30	..	..	8	9	5	3	..
BC	Na_2O—Na_3AlF_6	11	..	..	1	1	1	19	..	..	31	28	28	2	..	..	4	1	3
BD	Na_2O—CaF_2	11	..	1	..	1	11	15	..	31	..	35	56	1	..	4	..	9	1
BE	Na_2O—$NaSbO_3$	11	..	1	1	..	15	43	..	28	35	..	30	9	..	1	9	..	8
BF	Na_2O—ZnO	2	..	1	11	15	..	21	..	28	56	30	..	8	..	3	1	8	..
CD	Na_3AlF_6—CaF_2	8	1	..	..	1	5	36	31	..	..	49	18	2	4	..	..	10	3
CE	Na_3AlF_6—$NaSbO_3$	7	1	..	1	..	13	51	28	..	49	..	20	4	1	..	10	..	8
CF	Na_3AlF_6—ZnO	3	1	..	5	13	..	12	28	..	18	20	..	9	3	..	3	8	..
DE	CaF_2—$NaSbO_3$	13	1	1	..	..	13	27	35	49	..	..	23	10	9	10	..	..	3
DF	CaF_2—ZnO	11	11	5	..	13	..	22	56	18	..	23	..	5	1	3	..	3	..
EF	$NaSbO_3$—ZnO	15	15	13	13	..	..	30	30	20	23	..	..	3	8	8	3	..	..
	Average	9.2	6.5	5.1	7.5	9.0	8.9	27.6	30.6	29.2	31.2	33.6	26.0	5.3	4.6	4.6	4.8	6.5	5.1

Rating

1 Boric oxide
2 Sodium antimonate

3 Zinc oxide
4 Fluorspar

5 Sodium oxide
6 Cryolite

Rating

1 Sodium antimonate
2 Fluorspar

3 Sodium oxide
4 Cryolite

5 Boric oxide
6 Zinc oxide

Rating

1 Sodium antimonate
2 Boric oxide

3 Zinc oxide
4 Fluorspar

5 Cryolite
6 Sodium oxide

TABLE V (*continued*)

Impact on Edge						Impact on Center					
B_2O_3	Na_2O	Na_3AlF_6	CaF_2	$NaSbO_3$	ZnO	B_2O_3	Na_2O	Na_3AlF_6	CaF_2	$NaSbO_3$	ZnO
..	..	0.245	0.179	0.183	0.177	..	..	0.325	0.313	0.275	0.312
..	0.245	..	.154	.145	.150	..	0.325	..	.300	.338	.281
..	.179	.154	..	.173	.192	..	.313	.300	..	.331	.306
..	.183	.145	.173	..	.150	..	.275	.338	.331	..	.275
..	.177	.150	.192	.150	..	..	.312	.281	.306	.275	..
0.245	..	..	.276	.176	.292	0.325	..	..	.256	.310	.344
.179	..	.276	..	.253	.181	.313	..	.256	..	.275	.300
.183	..	.176	.253	..	.216	.275	..	.310	.275	..	.481
.177	..	.292	.181	.216	..	.312	..	.344	.300	.481	..
.154	.276	..	..	.230	.232	.300	.256	..	..	.250	.335
.145	.176	..	.230	..	.167	.338	.310	..	.250	..	.381
.150	.292	..	.232	.167	..	.281	.344	..	.335	.381	..
.173	.253	.230	..	..	.167	.331	.275	.250	..	..	.275
.192	.181	.232	..	.167	..	.306	.300	.325	..	.275	..
.150	.216	.167	.167	..	..	.275	.481	.381	.275	..	..
.175	.218	.207	.204	.186	.192	.306	.319	.312	.294	.319	.329

Rating

1 Sodium oxide
2 Cryolite
3 Fluorspar
4 Zinc oxide
5 Sodium antimonate
6 Boric oxide

Rating

1 Zinc oxide
2 Sodium antimonate
3 Sodium oxide
4 Cryolite
5 Boric oxide
6 Fluorspar

Average for the Series (all tests)

1 Sodium antimonate
2 Zinc oxide
3 Sodium oxide
4 Boric oxide
5 Fluorspar
6 Cryolite

RESULTS WITH CHANGES IN COMPOSITION

Series II

Type	Variables common to type enamel	Thermal Test (A) Boric oxide (B_2O_3)	(B) Sodium oxide (Na_2O)	(C) Cryolite (Na_3AlF_6)	(D) Fluorspar (CaF_2)	(E) Sodium antimonate ($NaSbO_3$)	(F) Zinc oxide (ZnO)
AB	B_2O_3—Na_2O	..	..	6	12	12	12
AC	B_2O_3—Na_3AlF_6	..	6	..	11	11	8
AD	B_2O_3—CaF_2	..	12	11	..	13	12
AE	B_2O_3—$NaSbO_3$	..	12	11	13	..	15
AF	B_2O_3—ZnO	..	12	8	14	15	..
BC	Na_2O—Na_3AlF_6	6	..	..	7	1	1
BD	Na_2O—CaF_2	12	..	7	..	11	7
BE	Na_2O—$NaSbO_3$	12	..	1	11	..	12
BF	Na_2O—ZnO	12	..	1	7	12	..
CD	Na_3AlF_6—CaF_2	11	7	..	..	9	11
CE	Na_3AlF_6—$NaSbO_3$	11	1	..	9	..	11
CF	Na_3AlF_6—ZnO	8	1	..	11	11	..
DE	CaF_2—$NaSbO_3$	13	11	9	..	..	15
DF	CaF_2—ZnO	14	7	11	..	15	..
EF	$NaSbO_3$—ZnO	15	12	11	15	..	..
	Average	19.4	8.1	7.6	11	11	10.4

Rating

1 Boric oxide
2 Sodium antimonate
3 Fluorspar
4 Zinc oxide
5 Sodium oxide
6 Cryolite

Acid Test

(A) B_2O_3	(B) Na_2O	(C) Na_3AlF_6	(D) CaF_2	(E) $NaSbO_3$	(F) ZnO
..	..	43	51	60	42
..	43	..	51	51	42
..	51	51	..	60	60
..	60	51	60	..	60
..	42	42	60	60	..
43	..	..	50	60	51
51	..	50	..	60	60
60	..	60	60	..	54
42	..	51	60	54	..
51	50	..	..	60	47
51	60	..	60	..	45
42	51	..	47	45	..
60	60	60	..	..	60
60	60	47	..	60	..
60	54	45	60	..	..
52	53	50	56	57	52

Rating

1 Sodium antimonate
2 Fluorspar
3 Sodium oxide
4 Zinc oxide
5 Boric oxide
6 Cryolite

Opacity

B_2O_3	Na_2O	Na_3AlF_6	CaF_2	$NaSbO_3$	ZnO
..	..	9	6	7	8
..	9	..	9	10	10
..	6	9	..	6	7
..	7	10	6	..	6
..	8	10	7	6	..
9	..	..	2	8	7
6	..	2	..	8	7
7	..	8	8	..	7
8	..	7	7	7	..
9	2	..	..	10	3
10	8	..	10	..	10
10	7	..	3	10	..
6	8	10	..	..	7
7	7	3	..	7	..
6	7	10	7	..	..
7.8	6.9	7.8	6.5	7.9	7.2

Rating

1 Sodium antimonate
2 Cryolite
3 Boric oxide
4 Zinc oxide
5 Sodium oxide
6 Fluorspar

Impact on Edge

B_2O_3	Na_2O	Na_3AlF_6	CaF_2	$NaSbO_3$	ZnO
..	..	0.184	0.161	0.164	0.178
..	0.184	..	.161	.177	.185
..	.161	.161	..	.198	.208
..	.164	.177	.198	..	.181
..	.178	.185	.208	.181	..
0.184	..	..	.255	.167	.185
.161	..	.255	..	.161	.183
.164	..	.167	.161	..	.181
.178	..	.185	.183	.181	..
.161	.255	..	..	.175	.186
.177	.167	..	.175	..	.175
.185	.185	..	.186	.175	..
.198	.161	.175	..	..	.166
.208	.183	.186	..	.166	..
.181	.181	.175	.166	..	..
.180	.182	.185	.185	.175	.183

Rating

1 Fluorspar
2 Cryolite
3 Zinc oxide
4 Sodium oxide
5 Boric oxide
6 Sodium antimonate

Impact on Center

B_2O_3	Na_2O	Na_3AlF_6	CaF_2	$NaSbO_3$	ZnO
..	..	0.362	0.337	0.325	0.343
..	0.362	..	.387	.456	.450
..	.337	.387	..	.475	.500
..	.325	.456	.475	..	.325
..	.343	.450	.500	.325	..
0.362	..	..	.337	.331	.331
.337	..	.337	..	.325	.387
.325	..	.331	.325	..	.331
.343	..	.331	.383	.331	..
.387	.337	..	..	.356	.393
.456	.331	..	.356	..	.331
.450	.331	..	.393	.331	..
.475	.325	.356	..	..	.387
.500	.387	.393	..	.387	..
.325	.331	.331	.387	..	..
.396	.341	.373	.388	.364	.378

Rating

1 Boric oxide
2 Fluorspar
3 Zinc oxide
4 Cryolite
5 Sodium antimonate
6 Sodium oxide

TABLE V *(continued)*

Average for the Series (all tests)

1 Fluorspar
2 Boric oxide
3 Sodium antimonate
4 Zinc oxide
5 Cryolite
6 Sodium oxide

RESULTS WITH CHANGES IN COMPOSITION

Series III

Type	Variables common to type enamel	Thermal Test (A) Boric oxide (B_2O_3)	(B) Sodium oxide (Na_2O)	(C) Cryolite (Na_3AlF_6)	(D) Fluorspar (CaF_2)	(E) Sodium antimonate ($NaSbO_3$)	(F) Zinc oxide (ZnO)
AB	B_2O_3—Na_2O	..	..	13	13	14	15
AC	B_2O_3—Na_3AlF_6	..	13	..	15	15	14
AD	B_2O_3—CaF_2	..	13	15	..	15	11
AE	B_2O_3—$NaSbO_3$	..	14	15	15	..	15
AF	B_2O_3—ZnO	..	15	14	11	15	..
BC	Na_2O—Na_3AlF_6	13	..	..	12	11	13
BD	Na_2O—CaF_2	13	..	12	..	13	11
BE	Na_2O—$NaSbO_3$	14	..	11	13	..	14
BF	Na_2O—ZnO	15	..	13	11	14	..
CD	Na_3AlF_6—CaF_2	15	12	..	..	15	15
CE	Na_3AlF_6—$NaSbO_3$	15	11	..	15	..	15
CF	Na_3AlF_6—ZnO	14	13	..	15	15	..
DE	CaF_2—$NaSbO_3$	15	13	15	..	..	14
DF	CaF_2—ZnO	11	11	15	..	14	..
EF	$NaSbO_3$—ZnO	15	14	15	14	..	..
	Average	14	12.9	13.8	13.4	14.1	13.7

Rating

1 Sodium antimonate
2 Boric oxide
3 Cryolite
4 Zinc oxide
5 Fluorspar
6 Sodium oxide

Acid Test (A) B_2O_3	(B) Na_2O	(C) Na_3AlF_6	(D) CaF_2	(E) $NaSbO_3$	(F) ZnO	Opacity B_2O_3	Na_2O	Na_3AlF_6	CaF_2	$NaSbO_3$	ZnO
..	..	60	60	60	60	..	..	9	5	5	4
..	60	..	60	60	60	..	9	..	4	5	6
..	60	60	..	60	60	..	5	4	..	2	1
..	60	60	60	..	60	..	5	5	2	..	2
..	60	60	60	60	..	..	4	6	1	2	..
60	..	..	60	60	60	9	..	..	3	4	6
60	..	60	..	60	60	5	..	3	..	1	5
60	..	60	60	..	60	5	..	4	1	..	1
60	..	60	60	60	..	4	..	6	5	1	..
60	60	..	..	60	60	4	3	..	..	6	4
60	60	..	60	..	60	5	4	..	6	..	5
60	60	..	60	60	..	6	6	..	4	5	..
60	60	60	..	..	60	2	1	6	..	..	2
60	60	60	..	60	..	1	5	4	..	2	..
60	60	60	60	..	..	2	1	5	2	..	..
60	60	60	60	60	60	4.3	4.3	5.2	3.3	3.3	3.6

Ratings

Not affected by the treatment.

Ratings

1 Cryolite
2 Sodium oxide
3 Boric oxide
4 Zinc oxide
5 Sodium antimonate
6 Fluorspar

Impact on Edge

B_2O_3	Na_2O	Na_3AlF_6	CaF_2	$NaSbO_3$	ZnO
..	..	0.188	0.209	0.202	0.180
..	0.188	..	.173	.169	.178
..	.209	.173	..	.194	.172
..	.202	.169	.194	..	.184
..	.180	.178	.172	.184	..
0.188	..	..	.169	.184	.168
.209	..	.169	..	.173	.177
.202	..	.184	.173	..	.169
.180	..	.168	.177	.169	..
.173	.169	..	..	.181	.191
.169	.184	..	.181	..	.177
.178	.168	..	.191	.177	..
.194	.173	.181	..	..	.175
.172	.177	.191	..	.175	..
.184	.169	.177	.175	..	..
.185	.182	.179	.181	.181	.177

Impact on Center

B_2O_3	Na_2O	Na_3AlF_6	CaF_2	$NaSbO_3$	ZnO
..	..	0.306	0.425	0.406	0.325
..	0.306	..	.450	.400	.394
..	.425	.450	..	.381	.387
..	.406	.400	.381	..	.319
..	.325	.394	.387	.319	..
0.306	..	..	.344	.356	.294
.425	..	.344	..	.256	.376
.406	..	.356	.256	..	.375
.325	..	.294	.376	.375	..
.450	.344	..	..	.331	.400
.400	.356	..	.331	..	.456
.394	.294	..	.400	.456	..
.381	.256	.331	..	..	.306
.387	.336	.400	..	.306	..
.319	.375	.456	.306	..	..
.379	.346	.373	.366	.359	.363

Ratings

1 Boric oxide
2 Sodium oxide
3 Fluorspar
4 Sodium antimonate
5 Cryolite
6 Zinc oxide

Ratings

1 Boric oxide
2 Cryolite
3 Fluorspar
4 Zinc oxide
5 Sodium antimonate
6 Sodium oxide

Average for the Series (all tests)

1 Boric oxide
2 Cryolite
3 Sodium antimonate
4 Fluorspar
5 Sodium oxide
6 Zinc oxide

regard to the effect of that difference. We may say, then, that in an *AB* type enamel, *C* produces a different effect than either *D*, *E* or *F*.

The next type of enamel would be the *AC* type with *B*, *D*, *E* and *F* as the differing constituents, thus—*ACB*, *ACD*, *ACE* and *ACF*. It is at once apparent that in an *AC* enamel, *B* produces a different effect than *D*, *E* or *F*. Following this procedure, the effects produced by the six variables may be compared and rated (Table V). Each enamel is used in three different comparisons for each test because each group of four enamels represents a distinct type and each enamel of that type is entitled to consideration regardless of the fact that it also falls in another type group.

From Table V it may be seen that the substitution of one constituent for another may improve an enamel of one type but not of another. There are ten comparisons for each constituent and by averaging the values they may be rated as to their general behavior in the particular test under consideration.

Sodium and boric oxides, which are not usually regarded as opacifying agents, are given ratings on their *ability to contribute* to the opacity. This ability was found to be greater in some cases than that of materials which are ordinarily considered as such. Although this result is contrary to general belief, it does not present an entirely new idea; in fact, such a possibility was discussed by R. C. Purdy and R. T. Stull[1] in 1908. It is believed that the greater fluidity resulting from the use of these two oxides allows a more complete dispersion of the included opacifying materials and that boric oxide may act to some extent as a mineralizer.

Although, as previously stated, it is evident from Table V that an ingredient which is beneficial in one enamel may have a detrimental effect in another, this fact does not necessarily indicate that the ingredient acts in an inconsistent way, nor does it conflict seriously with the theory that an enamel is a solution[2] (usually one containing suspended particles), the properties of which are approximately additive functions of the properties contributed by the individual constituents. The apparent discrepancy between these results and the theory is probably due to numerous indeterminate reactions which take place during the smelting of an enamel and its application.

The fact that a constituent does not always produce the same apparent effect in enamels of different composition makes any generalization difficult and any inconsistencies noted can reasonably be attributed to our lack of information regarding the constitution of materials of this type. There are, nevertheless, several general conclusions that may be drawn from the data in Table V.

For each series a list of the variable constituents, arranged in order of their general value in the enamels, has been prepared by taking the average rating of each material for all the tests. It seems that from such lists an idea may be obtained concerning the extent to which this average may be trusted to show the effect of any constituent when it is introduced in any particular enamel. In Series I, for instance, the first three constituents on such a list would be sodium antimonate, zinc oxide and sodium oxide. The enamel containing these three was No. 16 (Table II). This enamel did, in general, yield better results under the tests than any other in the series; however, it was a matt enamel. Further, the enamel con-

[1] "A Cheap Enamel for Stone Ware," R. T. Stull, Discussion, *Trans. Amer. Ceram. Soc.*, **10**, 225 (1908).

[2] H. F. Staley, *Jour. Amer. Ceram. Soc.*, **7** [10], 719 (1924).

taining the three constituents with low ratings was No. 5, which was among the four enamels having the poorest general standings in the series. On the other hand, such an analysis of the data would not indicate that the enamel containing sodium antimonate, sodium oxide and cryolite as variables (No. 12) would make an even poorer general showing than enamel No. 5.

In Series II the enamel containing the three high rating constituents was No. 8, which lacks only one place of being the best of the series in the tests. The enamel containing the three constituents of low rating (No. 13) was again among the poorest of the series.

The enamel containing the three constituents with the best average ratings in Series III is No. 6. It is among the better enamels, but is equalled or excelled in general by seven others of the series. Moreover, enamel No. 15 containing the three materials with low ratings is as good in general as the average of Series III.

Apparently, therefore, although lists can be compiled showing the average relative behavior of different ingredients, too much dependence cannot be placed upon them for guidance in determining the behavior of any particular combination of ingredients.

Considering one test at a time, the data in Table V permit of some interesting comparisons. The results of the thermal tests form a very definite basis for dividing the six variable constituents into three groups according to their contribution toward resistance to failure in this test. The agreement is good in all three series, except for cryolite, which is slightly irregular in Series III. The groups are: first, boric oxide and sodium antimonate; second, zinc oxide and fluorspar; and third, cryolite and sodium oxide. An average of the results in this test of all three series gave the six in the order named. It is interesting to note that the order is one of increasing expansivity factor with the single exception of sodium antimonate, which is doubtful. The factor for sodium antimonate has never been determined and must, therefore, be calculated from the factors for the constituent oxides.

In the acid test no comparative figures for the different variable constituents were obtained in Series III, because no enamel in that series was affected by the treatment. The results for Series I and II, however, agree very well. Sodium antimonate, fluorspar, sodium oxide and boric oxide are first, second, third and fifth respectively in both series, while cryolite and zinc oxide vary between fourth and sixth.

In the ratings for the three series according to opacity there are three noticeable irregularities, but these are not enough to upset the general order which would correspond to an average of the three series. Cryolite rates much lower in Series I than in II and III, sodium oxide rates higher in Series III than in I and II, sodium antimonate rates lower in Series III

than in Series I and II. Since each rating must be considered as indicating the action of the constituents of the kind of enamel used in the corresponding series, the value of a rating representing the average of all three series is doubtful. It is of interest, however, that with respect to opacity, the order prevailing in such an average would exactly coincide with the order in Series II, which represents most nearly the ordinary commercial type of enamel.

The ratings for mechanical impact show no consistency between the three series (Table V). In Series I, however, the order for impact-on-edge is the reverse of the order of the quenching test. This is in accordance with the theory herein advanced concerning the effect of expansivity on resistance to these tests. Furthermore, the orders for impact-on-center of Series II and III are very similar to those of the quenching test, a fact which also supports the theory. In Series II and III for impact-on-edge, and in Series I for impact-on-center, the order of expansivity factors corresponding to the oxides is irregular. Attention is again called to the fact that the expansivity is believed to be only one of the major factors affecting these properties of the enamels.

Conclusions

This paper deals entirely with white cover enamels applied to a standard ground coat of relatively low coefficient of expansion which is typical of commercial practice. The following conclusions are based on results obtained:

1. The coefficient of expansion is only one of the major factors affecting the ability of enamels to resist mechanical and thermal shock.
2. Resistance to quenching and to impact on parts of ware free to deflect, increases with decreasing expansivity of the enamels.
3. Resistance to impact on a curved surface, or part of ware not free to deflect, increases slightly with increasing expansivity.
4. Boric oxide and sodium oxide are conducive to greater opacity in some enamels when these constituents are substituted for a part of some of the materials ordinarily used as opacifying agents.
5. Replacing the customary flint content of the enamels by feldspar increases the resistance to impact-on-edge and decreases the resistance to impact-on-center, decreases opacity and resistance to quenching and acid attack.
6. In most cases replacing the usual feldspar content of the enamels by flint greatly increases resistance to quenching and acid attack and decreases opacity. This also slightly decreases resistance to impact on edge and center.
7. Enamels containing both silica and feldspar were, on the whole, most satisfactory for general use, but enamels having certain excellent proper-

ties, making them more suitable for special purposes, were found in Series I and III.

8. While generalities may be drawn regarding the usual effect of substituting certain constituents for others in an enamel, this effect sometimes varies with the type of enamel used.

NOTE: The authors are indebted to the Coonley Manufacturing Co. for the supply of steel dinner plates used in this work, also to T. D. Hartshorn for help in preparing and testing the enamels.

THEORY OF COAL MEASURE FIRE CLAYS[1]

By Ellis Lovejoy

I. Purification by Vegetation

Theory of Purification by Vegetation

The theory that coal measure fire clay deposits are clay beds purified by the growth of coal producing vegetation is very far from satisfactory and teachers of geology present it to their students with an apology for its weakness.

Quantity of Vegetation Growth Required

It is said that an inch of coal required a foot of peat and a much greater thickness of accumulation of the original vegetation. If this is approximately true, then a foot of coal required 12 feet of peat; 6 feet of coal required 72 feet of peat, and considerably over one hundred feet accumulation of the original vegetation. It is very doubtful if the roots of the growing vegetation (perhaps I should say rootlets) reached to such a depth in any great number; certainly, purification of the clay bed would practically cease when the depth of vegetable remains equaled the length of the roots of the growing vegetation.

If the theory of purification by vegetation is true and if it is assumed that the underlying soil was the same in each instance, then the majority of fire clay beds should have approximately the same thickness. The soil on which the beds grew could not be the same in character. The penetration of the roots would be much greater in some soils than in others. Where the penetration was shallow the clay beds should have been purified to a greater degree, but only to the depth of root penetration.

Clay Partings Not Purified

Sections of coal in geological reports show clay, soapstone (clay), and shale partings, which frequently are as thick as many fire clay beds under the coal. These partings were the soil in which grew the coal resting upon them. There evidently was no lack of sustenance for the subsequent coal growth nor are these partings pure clay, usually quite the contrary. The shale partings have not been purified nor have the lamination planes been broken up.

Clay Soil Not Necessary to Vegetable Growth

In two instances which have come to my attention, the partings were sandstone. The top coal must have grown in this sandstone and it seems evident in these instances that a base soil is not essential to the growth of coal vegetation.

The vegetation grew in swamps largely on vegetable muck, drawing the mineral salts from the water and decaying vegetation instead of from the underlying soil.

[1] Recd. Aug., 1925.

No Relation between Thickness of Coal and of Clay

On the theory of purification of fire clay beds by vegetable growth, thin beds of coal should be accompanied by thin beds of fire clay, and thick beds of coal should overlie correspondingly thick fire clay. To the contrary a mere streak of coal,[1] may have six to twelve feet or more of fire clay. The thick beds of coal are not notable for their fire clays. The Pittsburgh, and the Middle Kittanning ("Big Vein") in the Hocking Valley have clay of little value whereas the Lower Kittanning with a coal often too thin to be workable has a wonderful fire clay bed, likewise the Clarion and Tionesta.

The theory was bolstered by the explanation that the coals have been eroded and that the present coal thickness bears no relation to the thickness of the underlying clay. This is a weak prop in view of the fact that thin coals extend over wide areas and they are quite as regularly thin as are the thicker coals thick. The thin coals as well as the thick coals are often covered by clay shales and limestones which are not erosive since they were deposited in quiet waters.

Practically all the valuable fire clay beds are in the lower coal measures of the Appalachian basin which would not be the case if the theory had any ground in fact.

The old theory is untenable and should be abandoned whether we have a better explanation or none at all.

I. Clay, the Residual of Plant Decay

Wilbur Stout, of the Ohio Geological Survey, presented a new and unique theory; in brief,[2] that the clay beds are residual oxidized coal, or peat, namely, hydrated coal ash, and include altered foreign sediments, which explains the vagaries relative to the thickness of the clay beds and related coal beds. It also explains the quite close chemical composition of the numerous clay beds, and the physical structure.

The theory tersely stated by Mr. Stout is (Geological Survey of Ohio, Fourth Series, Bulletin 26):

> Under the theory outlined many of the relationships of clay to coal are easily explained. They were both swamp deposits formed during the periods plant life flourished there. The coals were derived directly from vegetable matter and the clay from terrigenous sediments augmented slightly by plant residues, both highly altered by the action of vegetation and its products of decay and by the action of various other reagents effective under such conditions.
>
> The clay deposits were gradually built up, thus receiving the maximum amount of purification. There was no break in the plant life, only a shifting of conditions from

[1] Often none at all except a stain nor even this in some instances.

[2] W. Stout, "Theory of the Origin of Clays," *Trans. Amer. Ceram. Soc.*, **17**, 557 (1915).

decay to preservation or from clay-forming to coal-forming stages. The quality of the clay is accounted for by the rate of deposition of sediments, the intensity of the chemical reactions, the duration of time such processes were effective, the condition of the water whether salt or fresh. In general, the theory explains satisfactorily the geological, chemical and physical features of clays, and harmonizes with the facts observed in the field.

Criticism of Stout's Residual Theory

That some fire clay deposits are stratified is the most pertinent objection to the theory as presented.[1]

Discussing Stout's theory,[2] it was stated that fire clays commonly were more sandy in the bottom. There are many exceptions to this rule of fire clay deposits being more sandy in the bottom. A notable exception is the Clarion clay in northern Pennsylvania where in a very limited area there is sandy clay in the top, in the middle and in the bottom. Sometimes the three sand stratas are interstratified with the more plastic clay.

Fire clays as a rule do not have stratification planes, neither do many sandstones nor rock shales in strata equivalent in thickness to fire clay beds. The fire clays are quite regular in thickness over wide areas and have definite floors and roofs, and an occasional bed is definitely stratified.

It is difficult to conceive that residual oxidized swamp deposits including terrigenous material could have the regularity of the fire clay deposits. It is also difficult to conceive that in every fire clay bed we would not find frequent inclusions of lenticular beds of coal which had escaped the oxidation, yet such inclusions are extremely rare.

If either the purification or residual theory is fully true, fire clay should be found under peat beds, but districts where peat abounds are not producers of fire clays.

III. Fire Clays as Altered Sedimentary Material

The vegetation in the great coal basin grew as a fringe around the basin and likely on islands within the basin, advancing as the basin filled with sediment or as the floor of the basin was elevated by seismic disturbances. In major subsidences the swamp growth was buried under masses of rock sediments (representing the intervals between the coal beds) and another swamp developed when the conditions were made favorable by subsequent elevations.

It is a reasonable assumption that the fire clay beds are truly stratified; that they are the flotsam and jetsam from the great fringe, floating out into the basin and building up a deposit to the water level and thus preparing the way for the advance of the vegetable growth.

The basin was of great extent, with internal currents, subject to low

[1] G. H. Ashley, *Jour. Amer. Ceram. Soc.*, **2** [10], 790 (1919).

[2] *Loc. cit.*, **17**, 557 (1915).

tides, and variously agitated by winds and waves, thus keeping the more or less flocculent clay material floating, spreading it farther and farther out into the basin.

Torrential rains flooded the swamps with sediments. The vegetation digested these sediments, disintegrated them, and added its quota of oxidized residue to them. The ebb carried these sediments and the waste of the vegetation out into the basin. Thus were the fire clay beds formed distinctively different from the beds of shale and sandstone which accompanied them. The latter are purely sediments swept into the basin direct from the upland while the former have gone through the swamp belt and been purified. Both, however, are sedimentary in origin.

Since the fire clay sediments were largely flocculent they would be slow in settling and since they would be less intermittent than the simple flood sediments, we would not expect them to settle in laminae as do the shale sediments; instead we would get the structureless mass of a fire clay. In a number of instances, however, fire clays are decidedly shaley in structure which is evidence of their sedimentary origin.

It seems a bit significant that the greater fire clay beds are in the lower measures. As the basin filled with sediments it became smaller and likely shallower. Instead of a great basin fringed with a wide border of advancing vegetation, it became more nearly a swamp throughout its area, with long wide promontories reaching out into the area, many islands, large and small, dividing the area into a series of stagnant lakes, eliminating any tidal movement, reducing the wave action, and curtailing the currents. Under such conditions the sediments from the coal growth would have only limited opportunity to build up large and wide reaching deposits, while on the other hand we must strain a point to assume that residual oxidized material had not a development opportunity equal to that in the lower measures.

If peat bogs are not underlaid by clay may it not be due to the fact that the basin was small and did not permit sedimentation, yet the small size would not prevent residual oxidized material? Fire clay beds do not seem to me to be simple upland sediments, nor are they such sediments purified by the growth of vegetation on them, instead they are upland sediments which have come down through the swamp and perhaps undergone some alteration by contact with the swamp growth and decay, particularly in the iron minerals, together with waste sediments from the swamp itself. In some beds the altered sediments may predominate, and in others the swamp waste.

I take this to be Stout's theory. In some instances these swamp sediments may be intermingled with simple upland sediments entering the basin through direct channels.

The beds are not residual deposits, instead they are stratified sedimen-

taries which have drifted out into the basin in advance of the coal growth, and have developed the condition for the extension of the vegetation. The swamp vegetation is the mother bed of the fire clay beds.

IV. Application of Sedimentary Theory

The clay in Southern Ohio underlying the lower Mercer limestone, and formerly known as the Lower Mercer fire clay, is now designated as the Middle Mercer clay. Below this comes the Flint Ridge coal and fire clay. In some places, notably Union Furnace, Ohio, the two clays are together without the separating Flint Ridge coal, but with a dark streak which is probably the mark of the Flint Ridge coal. Elsewhere the two beds are separated by several feet of shale or sandstone.

Similarly the Tionesta and Brookville clays come together in some places and elsewhere are separated by shale up to fifteen or more feet.

At Oak Hill the flint clay rests on the Lower Kittanning coal, and both it and the plastic clay under the coal are worked. At Hamden, Ohio, the Oak Hill coal is over a foot or more of the Oak Hill flint clay, below which is the Lower Kittanning coal underlaid by a deep bed of the Lower Kittanning clay. These beds are contiguous. In other localities the two members in the scale are separated by 15 to 20 feet of shale.

The Middle Mercer and Flint Ridge clays are very much alike. The Tionesta and Brookville are notably different, especially in weathering characteristics.

The Oak Hill and Lower Kittanning in the Oak Hill district are totally different, one being a flint clay and the other a sandy plastic clay.

Explanation by Stout's Theory

Under Stout's theory, in each instance where the beds are contiguous, the growth of the vegetation is assumed to have been continuous and with this, where no streak of coal separates the beds, the oxidation to have been coincident with the vegetable growth. Where the coal intervenes, oxidation would have ceased and preservation prevailed for a time, followed by oxidation and the period closed with preservation and final submergence.

Where shale or sandstone splits the beds, the development of the lower bed in each case is assumed to have ceased and elementary sediments covered it, followed by subsequent growth of vegetation over the sediments. This involves local subsidence and subsequent elevation.

Explanation by Sedimentation Theory

It seems more reasonable to assume that these beds are altered sedimentaries instead of residuals. At the close of each period of the lower bed there was some elevation, permitting the vegetation to advance over the accumulated sediments and thus develop the streak of coal or its mark. This was followed by subsidence. The influx

of elementary sediments which would follow filled the hollows in the underlying altered sediments until equilibrium was established, then coal-forming material again accumulated building up the second bed on the underlying shale and clay sediments. Thus we would have the later bed of fire clay in some places resting immediately on the lower bed and elsewhere there would be an intervening belt of shale or sand.

The period closes with either the filling of the basin in front of the coal growth to permit the advance of the vegetation over the sediments, or by elevation of the clay to the water level thus permitting coal growth, and finally submergence, followed in the instances of the Lower Mercer and the Brookville by limestone formation. The following quotation[1] is pertinent.

> In the Appalachian fields the Pittsburgh, Waynesburg and Washington, in the upper portion of the series, approach as nearly to continuity as one may conceive, for they are always present in exposures and records within an area of thousands of square miles; but the Pittsburgh shows remarkable variations in thickness; it thins away to nothing from all sides toward the central part of the area, while at times only its under clay remains to mark the horizon.

It cannot be assumed that the Waynesburg and Washington swamps were from the beginning covered with vegetation, instead from the very nature of swamps the growth was a net work of vegetation enclosing lagoons and lakes which gradually filled with the waste from the vegetation and as the filling proceeded the vegetation closed in.

May it not be that the under clay which "remains to mark the horizon" of the Pittsburgh is the advanced front of the clay sediment which did not come to the surface to permit the growth of the coal over it, and is it not evident that smaller swamps did not possess essential conditions for large beds of fire clay?

480 W. 6TH AVE.
COLUMBUS, OHIO

[1] J. J. Stevenson, "Formation of Coal Beds."

COMPARISON OF METHODS USED IN ESTIMATING THE MATURING OF TERRA COTTA[1]

By Louis Anderson

ABSTRACT

The purpose of this investigation is to develop some means to better determine the maturing of terra cotta ware in the firing.

These tests were made at the American Terra Cotta Company's plant in a down-draft kiln. The kilns were fired from 110 to 120 hours, a Thwing pyrometer showing about 1115°C at the finish. The pyrometer was located half-way between the bottom and top of the kiln and within a few inches from any of the test pieces and cones.

Test Number 1

The first test made was to compare Orton cones, Mayer cones, red slip trials used by the Midland Terra Cotta Company and shrinkage trials used by the American Terra Cotta Company.

The red slip trials used by the Midland Terra Cotta Company are made of a regular body mixture dipped in red slip. The temperature is determined by the color; the greater the heat the darker they are.

The shrinkage trial used by the American Terra Cotta Company is a regular body clay free from grog and dry pressed into a wedge-shaped piece. The only moisture in the clay when pressing into shrinkage test piece is that which it contained at the time of grinding. The gage used to measure this shrinkage is graduated to .1%.

At about 1100°C with the kiln progressing about 3° an hour the first red slip and shrinkage trials were drawn and cones read. This was repeated every two hours until the finish of the run.

Result The red slip trial changed in color every two hours until two hours previous to the highest temperature. From this time on, it was possible to arrange the trials in the order in which they were taken from the kiln by the texture rather than by the color.

The shrinkage trials showed a fairly gradual shrinkage up to the highest temperature and for four hours after fires were drawn and the pyrometer had started down.

Mayer cones No. 3 continued to advance for two hours after the shrinkage trials stopped. One of the Mayer No. 3 cones did not start until the other was nearly down. At this time the shrinkage trial stopped, Orton cone No. 4 was bent and remained in this position.

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[1] Presented at the Annual Meeting, American Ceramic Society, Feb., 1925. (Terra Cotta Division.)

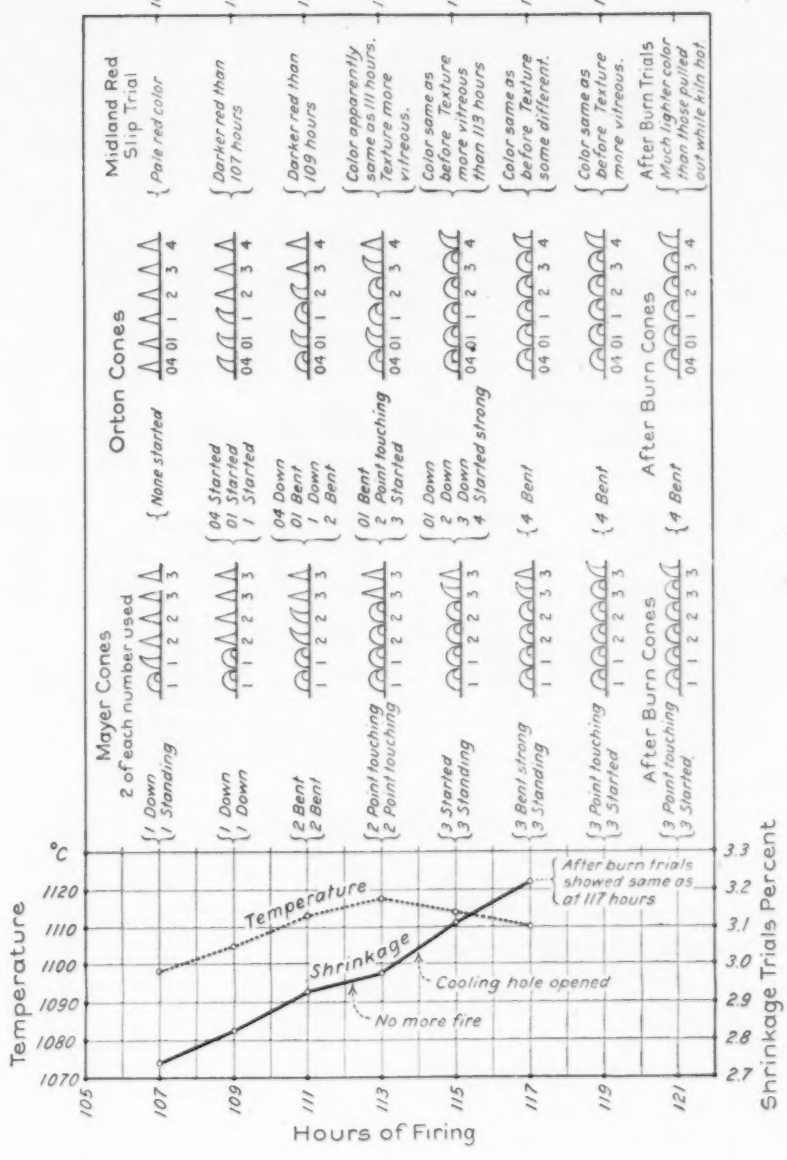
Mayer Cones
2 of each number used
Orton Cones
Midland Red
Slip Trial
1 Down
1 Standing
None started
Pale red color
1 Down
1 Down
04 Started
01 Started
1 Started
Darker red than 107 hours
2 Bent
2 Bent
04 Down
01 Bent
1 Down
2 Bent
Darker red than 109 hours
2 Point touching
2 Point touching
01 Bent
2 Point touching
3 Started
Color apparently same as 111 hours. Texture more vitreous.
3 Started
3 Standing
01 Down
2 Down
3 Down
4 Started strong
Color same as before. Texture more vitreous than 113 hours
3 Bent strong
3 Standing
4 Bent
Color same as before. Texture some different.
3 Point touching
3 Started
4 Bent
Color same as before. Texture more vitreous.
After Burn Cones
3 Point touching
3 Started
4 Bent
After Burn Trials
Much lighter color than those pulled out while kiln hot
°C
Temperature
Shrinkage
After burn trials showed same as at 117 hours
Cooling hole opened
No more fire
Hours of Firing
Shrinkage Trials Percent

FIG. 1.

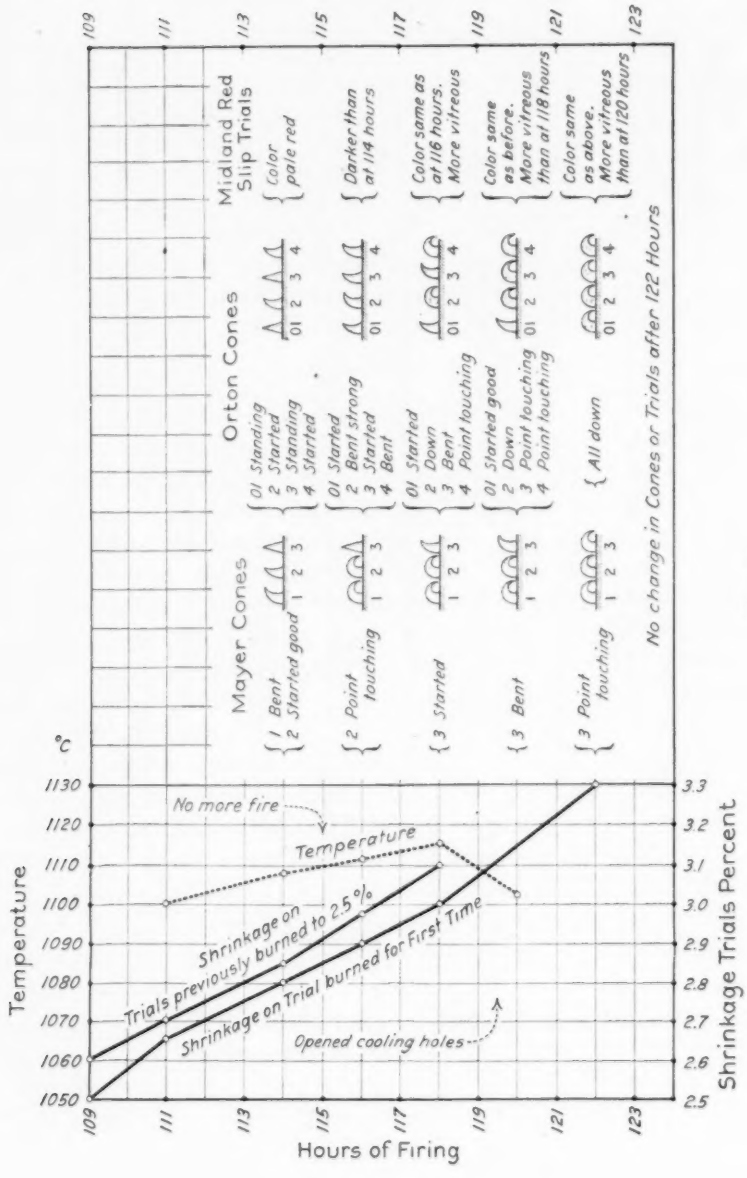
Mayer Cones
Orton Cones
Midland Red Slip Trials
°C
Temperature
Shrinkage Trials Percent
Hours of Firing
No more fire
Temperature
Shrinkage on Trials previously burned to 2.5%
Shrinkage on Trial burned for First Time
Opened cooling holes
No change in Cones or Trials after 122 Hours

FIG. 2.

Test Number 2

As a check on the first test, another was made to see the effect on the color of dipping the red slip trial, when hot, in water.

A comparison was made of shrinkage trials fired for the second time and a raw trial at various temperatures near the finish of the firing. The trials used were fired the first time at 1065°C or 2.5% shrinkage. The trials that were put in raw on the second firing showed 2.5% at 1060°C. The refired shrinkage trials showed an accumulation of shrinkage, it being 2.6% or .1% more than the shrinkage of the first fired trial. The refired trial continued to show a shrinkage of about .1% until three hours after the last firing of the kiln.

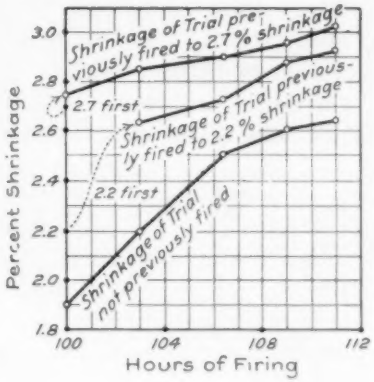

FIG. 3.

The red slip trials were broken in two, and one-half dipped in water while very hot. This apparently had no effect on the color aside from a few streaks of light scum. In other respects the red slip trials showed the same as the first test.

The shrinkage trials continued to shrink for four hours after the pyrometer had started down, at which time the Orton and Mayer cones stopped.

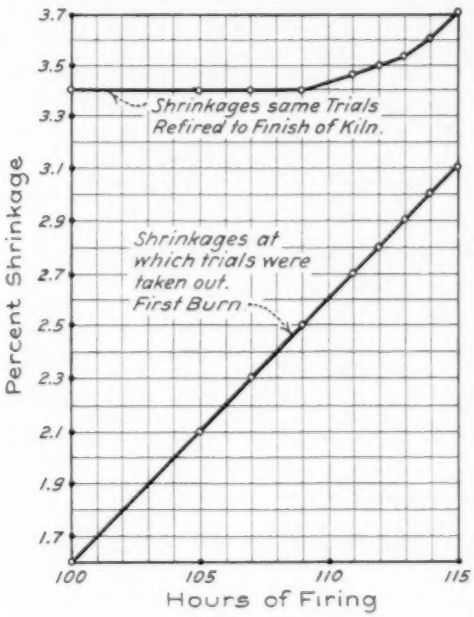

FIG. 4.

Test Number 3

The next test was a check on the refiring giving a greater shrinkage at the same heat or less. Trials going into the kiln for the second firing were previously fired to 2.2% and 2.7% shrinkage and were arranged to be taken out with trials which were in for the first time.

At the time when a regular trial showed 1.9% shrinkage, one which had been previously fired to 2.2% showed 2.6½% shrinkage. The trials fired to 2.7% on the first firing advanced

to 2.8½%. The refired trials continued to shrink more than .3% throughout the firing period and two hours of soaking.

Test Number 4

This test was made with shrinkage trials to determine what further shrinkage those in the first firing would have on a second firing if fired at about 1130°C. The trials were fired the first time at various shrinkages from 450°C to 1115°C.

These trials with some raw ones were placed in a sagger and fired in a regular way. The trials fired for the second time showed further shrink-

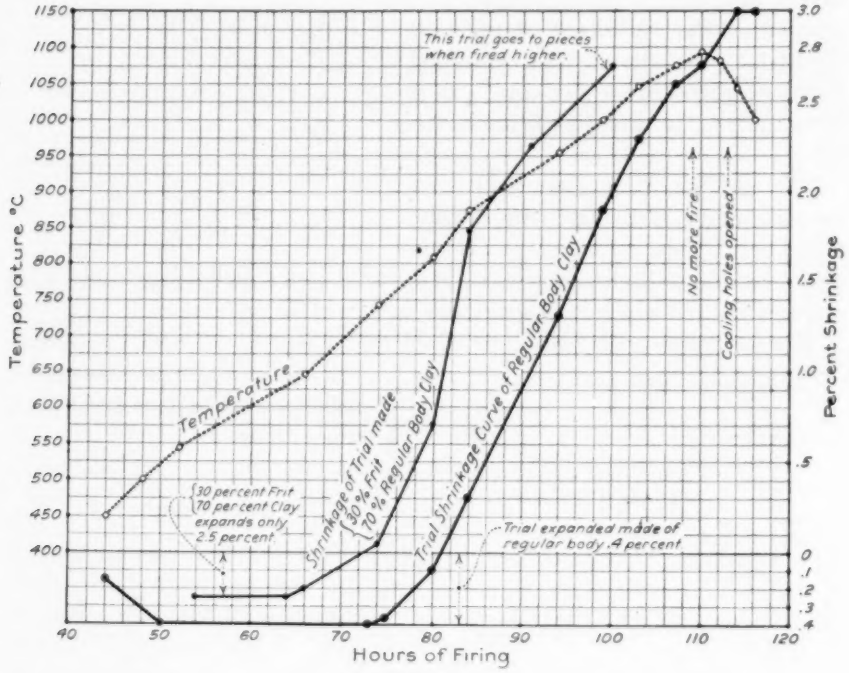
Temperature °C
Percent Shrinkage
Hours of Firing
Temperature
This trial goes to pieces when fired higher.
Shrinkage of Trial made 30% Frit 70% Regular Body Clay
Trial Shrinkage Curve of Regular Body Clay
30 percent Frit 70 percent Clay expands only 2.5 percent
Trial expanded made of regular body .4 percent
No more fire
Cooling holes opened

FIG. 5.

age up to 1060°C which is 2.5% shrinkage. From 2.5 to 3.1% the shrinkage increased until the trials fired to 3.1% the first time, showed 3.7% on the second firing, instead of 3.4% shrinkage on trials in for only one firing.

Test Number 5

We find a trial very useful composed of 70% body clay and 30% of frit ground fine.

The straight clay at 400°C contracts to .2%. At 450°C it starts to expand, there being .4% expansion at 525°C. It remains at this expansion

until 775°C, at which time it again contracts reaching its original size at 825°C.

With the 30% frit the expansion of the trial is only .25%. It also shows a shrinkage about ten hours sooner than does the straight clay.

At 1025°C when the straight clay shows a shrinkage of 1.0% the frit trial shows 2.2%.

Conclusion

Previous to 1912 a red body, dipped in red slip, was used as a guide in firing. This was apparently not giving results.

A small trial was cast and used as a shrinkage trial. This trial proved to be so good that a machine was used to press them.

In 1916 the red slip trials were given another chance for about four months. We used these in connection with cones and shrinkage trials. The slip color, being so uncertain, the color trials were discontinued. I believe a mixture could be made so that the change in color could be determined much better than at present.

I found that a slip made with manganese as a coloring was the most sensitive to changes of heat.

A trial could be made with one end for shrinkage and the other for dipping. I would not care to rely on shrinkage trials alone, although I believe if these were made with the same pressure and with moisture reasonably even, they would be reliable. We regulate the evenness of the kiln by shrinkage trials. A couple of cones are used and taken into consideration when determining the finish. A shrinkage trial, fired not too high the first time, is used very nicely to place in kiln at different parts for measuring shrinkage after the kiln is unloaded. These differences in temperature in different parts of the kiln are good facts to know.

TERRA COTTA, ILLINOIS

NEW TYPE OF OXY-ACETYLENE FUSION FURNACE, WITH NOTES ON THE BEHAVIOR OF REFRACTORIES AT CONE 40[1]

By A. F. Gorton and W. H. Groves

ABSTRACT

The furnace described in this paper differs from the usual type of fusion furnace in that acetylene is used as fuel and the burner is applied vertically instead of horizontally. Advantages offered by this novel design are rapidity and uniformity of heating, convenience as regards regulation and observation of the cones, economy of operation and simplicity of maintenance.

Introduction

Recent experiments at the Bureau of Standards[2] and the Bureau of Mines[3] with the granular carbon resistor furnace and the Northrup induction furnace have aroused considerable interest in softening point furnaces of the electrically heated type. While electricity as a fuel has certain inherent advantages, most ceramists have preferred to put their trust in results obtained with gas-fired furnaces. It is well known that the electric furnace is speedy, convenient to operate, as regards temperature regulation, and capable of reaching very elevated temperatures. It is quiet-running, and does not require a stack; hence the operator may observe with considerable comfort the progress of the fusion. These advantages are all afforded perhaps to a greater degree by the induction type than by the more familiar granular carbon resistor. The most prevalent objection to the use of these furnaces is the injurious effect of the reducing atmosphere[4] necessarily associated with white-hot carbon or graphite, it being well known that the Seger cones as well as those of clay deform at temperatures much below the normal softening point, if carbon monoxide is present. Although the Bureau of Standards has shown[5] that reduction may be avoided by passing air or oxygen slowly through the furnace chamber, this requires much extra apparatus. The Arsem vacuum type of furnace, which employs a spiral graphite resistor, is not free from this reducing action, though it has been used by Kanolt[6] to effect the fusion of oxides at temperatures up to 2800°C.

The expense of the electrical equipment is perhaps a graver objection, especially as regards the Northrup type of induction furnace, which

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[1] A summary of this paper was presented at a meeting of the Chicago Section, American Ceramic Society, April 14, 1925. Recd. Aug. 10, 1925.

[2] W. L. Pendergast, *Jour. Amer. Ceram. Soc.*, **8** [5], 319–25 (1925).

[3] Andrews, Bole and Withrow, II, *Jour. Amer. Ceram. Soc.*, **8** [3], 171 (1925). Also P. D. Helser, "A Laboratory Load Furnace," to appear in *Jour. Amer. Ceram. Soc.*, December, 1925.

[4] Andrews, Bole and Withrow, *loc. cit.*, p. 185.

[5] Pendergast, *loc. cit.*

[6] Bur. Stand., *Tech. Paper* **10.**

operates by means of condensers and other high-frequency circuit devices. The transformer and rheostat required for the ordinary granular carbon furnace are fairly expensive (about $250, according to Pendergast), though it must be acknowledged that the cost of power consumed per test is low. The question of portableness is also to be considered. Although fusion tests have been performed hitherto mostly in the laboratory, and not at the mine, it is advantageous to be able to transport the equipment, as Wilson[1] points out. The electric furnace is not very portable, being dependent on electric current which is not available everywhere. The acetylene furnace and gas tanks can easily be transported. Many industrial establishments lack the necessary power supply required to operate an electric furnace, for the reason that three-phase, 25-cycle current is very prevalent, and since the furnace operates on single-phase, it would be necessary to install an extra supply line, to keep from disturbing the balance of the main transformers.

FIG. 1.

The present furnace was designed for rapidity and uniformity of heating, rather than economy and portableness, though the latter are features that will appeal to many ceramists. The temperatures attainable with a furnace of this design exceed those claimed for pot furnaces fired with natural gas or oil, and the coke-fired Deville furnace. The limiting feature is probably the refractoriness of the plaque, since this part receives the full blast of the flame. The supporting pins also are subject to deformation above cone 40.

General Design

The furnace with stand and torch in position, ready to operate, is shown in the accompanying photograph (Fig. 1). This view shows clearly the smallness of the furnace proper relative to the height of the stand. The operator while seated may sight conveniently through the slot at the cones within the furnace chamber. At the same time the torch is within easy reach, so that he can make adjustment of the gas and work the counterpoise which raises and lowers the burner. Ordinarily, the gas mixture is adjusted but once, at the beginning of the run. For instance, if using

[1] Hewitt Wilson, "An Oxy-Acetylene High Temperature Furnace," *Jour. Amer. Ceram. Soc.*, **4**, 835 (1921).

a No. 10 tip, the oxygen is adjusted at ten pounds gage pressure, and the reducing valve on the acetylene is set to give a similar pressure. If the larger tip (No. 12) is being used, both oxygen and acetylene are adjusted at twelve pounds. Though our experiments so far have been conducted with acetylene and oxygen, it should be understood that oxy-hydrogen and natural gas-air or other gaseous fuels would be suitable, depending on the maximum temperature to be reached in the test. In fact, it would be desirable, for the sake of economy as well as for preservation of the lining, to preheat with natural or city gas.

Sectional View

The lining and the refractory pins which support the cone plaque are shown clearly in Fig. 2. The cones are symmetrically located near the periphery of the plaque proper, which rests on a supporting plaque, which in turn rests on the pins.

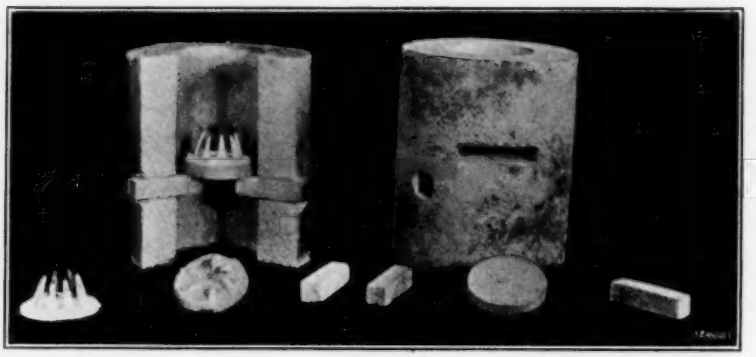

FIG. 2.

The pins are square in cross-section and fit loosely in square holes cut through the lining and steel shell, these holes being 120° apart, as shown. Although it is possible to replace a pin while the furnace is hot, experience shows that this is rarely necessary. Breakage of a pin during operation will tilt the plaque to a dangerous angle, but the cones will not upset. It is an advantage to be able to make the necessary repair by thrusting a steel rod up from below and supporting the plaque in this manner while a new pin is being substituted for the broken one.

Composition of Refractory Parts

Electrically fused (white) magnesia is the material used in forming the lining, plaque support and pins, although the "double dead-burned magnesite" is satisfactory provided cone 36 is not exceeded. Above cone 36 ordinary magnesite softens, due to the high iron content, and at cone 39 the pins and plaque support were found to warp badly. The lining was formed by tamping in a steel mold, the bond being milk of magnesia, or

water. The plaques and pins were also "dry-pressed," using the same mixture. The amount of liquid should not exceed 5% by weight. As is well known, magnesite shapes are tender, or difficult to dry, and cracking is apt to develop. The preliminary firing should be done carefully in a small kiln and carried preferably to a temperature of 2600°F. The lining is thus under-fired at first, but after a few fusions the lining vitrifies on the inner surface. Since a furnace of these small dimensions loses heat rapidly through the side walls or "radially," there is a steep temperature gradient in this direction, which of course tends to preserve the steel jacket, as well as to prolong the life of the lining. Moreover, it appears desirable not to check this radial flow of heat by too thick insulation. We found that $1/4''$ soft asbestos was satisfactory as insulation between the lining and the steel jacket.

Supporting Stand and Torch Holder

The base on which the furnace rests is of angle iron, acetylene welded. The height of the stand is 36″, and the floor area covered is 24″ x 24″. The height of the slot with furnace resting on the stand is 42″, hence is practically on a level with the operator's eyes. The torch holder consists of a steel plate bearing a projecting arm to which the torch is clamped. This plate slides easily in vertical guides, the total travel being 10″. The torch is raised and lowered by a chain which passes over a sprocket at the top and ends in a counterpoise. A handle is provided at the front for controlling the position of the torch. All these details are shown in Fig. 1.

The torch is a special model with tip bent at quite an angle, and is furnished by the Torchweld Equipment Company of Chicago. This company furnishes also the gages. The tip used is either No. 10 or No. 12, the latter being the larger size and more effective at high temperatures. Adjustment of the gage pressures is made such that if No. 10 tip is used, the oxygen and acetylene are each regulated to ten pounds pressure and similarly for the larger tip.

Visibility of Cones

As shown in the illustration, a slot in the front wall of the furnace affords the operator a clear view of the cones within the furnace chamber. It is thought that this feature, which can be appreciated only by those who have run fusion tests, distinguishes this apparatus from a great many fusion furnaces of the electric as well as gas or oil variety. In the old pot-furnace (gas-fired), it was necessary to lift the cover or baffle on top and peer in at quite an angle, in order to catch a glimpse of the white-hot cones. This is also necessary in the case of the granular-carbon and induction furnaces mentioned above. The same is true of Wilson's acetylene furnace. In the furnace here described, the reason why the cones show up so clearly is that the background or opposite wall is slightly cooler than

the chamber proper and the cones, due to loss of heat radially as previously described. Hence the cones appear brighter than the lining.

Economy of Operation

A furnace of this type is practically a chimney, the hot gases being baffled, first by the plaque, and next by the baffle at the top of the furnace. Accordingly, the fusion chamber proper is comprised between the plaque and the top baffle—which is the hottest portion of the apparatus. Equilibrium at any temperature is characterized by an equality between the input of heat and the loss through the walls, top exit and by reflection from the bottom plaque. Although the furnace is very small, hence can be rapidly cooled or heated, it is easy to secure uniform heating of the plaque, since the full force of the flame is applied from below, in a vertical direction, and the flame sweeps upward around the edge of the plaque, uniting above the cones. Tests performed by placing 6 cones of the same number on a plaque showed equality of fusion at all points. Irregular results appeared only in case the rate of heating was excessive (*i. e.*, cone 30; in less than 20 minutes, starting from room temperature).

Several dozen tests of a wide variety of refractory substances have shown that the furnace is economical as well as speedy. After the first fusion, one naturally saves time because the plaque and lining are already hot, and it is possible to reach temperatures such as cone 36 in fifteen minutes. Cone 40 was the highest point reached, but this, of course, is not the upper limit. From our experience, we estimate that a fusion test will average about $0.30, including oxygen as well as acetylene. This figure exceeds that given for the electric furnace by Pendergast,[1] but equals the cost of operation of Wilson's acetylene furnace.

Results Obtained

A few typical results are given herewith:

	Cone
Tennessee Ball (J. P. No. 11)	33
English China Clay	32½
South Carolina Kaolin	34½
Cement ("Alumite")	35
Cement ("Arcofrax")	36½
Cement (chiefly Alundum)	39
Fire Brick ("American")	34
Fire Brick (E. & H. "Acme")	31
Fire Brick (Savage No. 1)	29½

Notes on Behavior of Refractories at Elevated Temperatures

At temperatures above that corresponding to cone 32, we observed interaction between the various refractory materials in close contact within

[1] *Loc. cit.*

the furnace chamber. Thus, fire clay and magnesia react to some extent beginning at cone 32, and alumina reacts with chrome above cone 36. Also, there is a zircon-magnesia reaction at about cones 37–38. It is this chemical action which makes difficult the determination of fusion points at elevated temperatures. Since we used magnesite for the supporting plaque, it was necessary to use a thin layer of chrome cement between this and the cone plaque, which was usually made of a mixture of alumina and kaolin. We noticed the familiar chrome-alumina pink tinge on cones and plaque when heating to cone 36 and above. A fusion test on zircon (zirconium silicate) failed for this reason, though a cone formed from a zircon brick (manufactured by Carborundum Company) showed some deformation above cone 32. It might almost be said that, at these elevated temperatures, a fusion test should be performed in a furnace where the lining, plaque, etc., are of the same composition as the material under test. Although, in this manner, chemical action would be avoided, objection might be raised on the ground that the refractories would suffer serious deformation during a single test.

Conclusion

In developing this new type of gas-fired fusion furnace, it has been our aim to take full advantage of the possibilities for rapid heating offered by the familiar acetylene torch, while at the same time retaining those features which ceramists have considered characteristic of gas-heated furnaces, namely, the oxidizing nature of the furnace atmosphere, and real uniformity of temperature throughout the furnace chamber. To these we have added convenience of regulation not excelled by the electric furnace, low cost of equipment and operation, and simplicity of maintenance. The operator can manage the furnace with a maximum of comfort, owing to the small size of the furnace and the small amount of radiation. A point especially noteworthy is the ease with which the cones may be viewed throughout the fusion period, due to the slot in the side of the furnace. Finally, this is the only fusion furnace which is portable in the strict sense of the word, since it can be carried easily in one hand.

The Western Electric Company, Incorporated, has applied for a patent covering those features of the furnace which are considered of sufficient novelty, namely, the mechanism for raising and lowering the burner, and the means for supporting the cone plaque.

Ceramic Division, Hawthorne Works
Western Electric Company
Chicago, Illinois

A MACHINE FOR TRANSVERSE TESTS OF CLAY AND GLASS LABORATORY SPECIMENS[1]

By A. C. Harrison

ABSTRACT

A machine for transverse testing which is easily adjusted, positive acting, and accurate for both light and heavy loads. Results are shown on vitreous china bodies and glass.

Introduction

This machine was designed to test the transverse breaking strength of clay and glass laboratory specimens of widely varying dimensions and strength. In order to test such specimens upon a single machine, it is essential to have high accuracy at both large and small loads and also means of varying the span and lever multiplying power. The machine is sufficiently flexible to test specimens varying from the smallest practicable size to one $2^1/_2''$ x $2^1/_2''$ x $21''$, and has satisfactory accuracy for direct loads varying from 2 to 1500 pounds. The Bureau of Standards[2] has recently developed three portable transverse breaking machines for testing whole brick, and various commercial machines[3] are also available which answer ordinary laboratory requirements for testing specimens of a practically uniform size and shape.

Description

General Description A beam and a lever (Fig. 2) constitute the active element of this machine. An adjustable counterpoise C and a weight W are suspended from the right-hand arm of the beam, and are approximately balanced by a bucket of shot B suspended from the left-hand arm and the weight of the lever acting through the connecting member w or x. An exact balance is accomplished by means of the counterpoise C.

Bucket and Valve The bucket is equipped with an automatically operated valve (Fig. 4) which controls the flow of shot. A scoop R (Fig. 2) catches the shot flowing from the bucket and a spring balance, supporting the scoop, registers its weight. The rate of flow of shot is regulated by placing special brass bushings in the valve, and any desired rate can be obtained by using a bushing of the proper inside diameter; however, only two have been found necessary. Two solenoids and three switches (Fig. 4) operate and control the valve. It

[1] Printed by permission of the Director of the Bureau of Standards, Department of Commerce. Recd. Sept. 23, 1925.

[2] *Tech. Paper* **251**; *Bull. Amer. Ceram. Soc.*, **4** [8], 407(1925); *The Clay-Worker*, Feb. 28, 1925.

[3] The Olsen, Riehle and Fairbanks are among the foremost on the present-day market.

opens, and starts the flow of shot, upon closing the electric circuit through a hand-operated spring contact F (Fig. 4); and it closes and stops the flow of shot, upon closing the circuit through another hand-operated spring contact S (Fig. 4), or through the automatic switch S' on the beam of the machine.

Valve Mechanism

The valve mechanism indicated in Fig. 4 operates as follows: when slide a (actuated by solenoids s and s', for which the electric current is supplied by eight dry cells) occupies its extreme right-hand position, its orifice is in line with a similar one in the bottom of the bucket and shot is free to flow; and when the slide occupies its extreme left-hand position the orifices are not aligned and the flow is shut off. Hence, by energizing solenoid s' the slide is pulled to the right and shot begins to flow, and by energizing solenoid s the slide is pulled to the left and the flow is stopped. Upon beginning a test the valve is opened by means of switch F (Fig. 4), and upon failure of the specimen it is closed by means of the automatic switch S' (Fig. 4). The automatic switch is attached to the beam of the machine and closes when the beam falls below a horizontal position; consequently, upon rupture of a specimen, the clockwise rotation of the beam closes the switch and the flow of shot is quickly stopped.

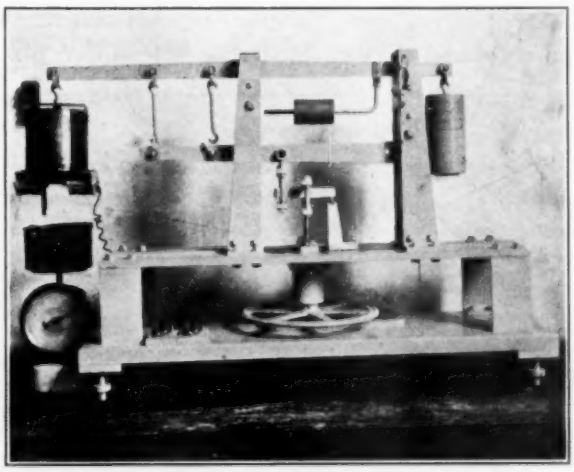

FIG. 1.—Showing lever combination of lowest multiplying power.

Straining Mechanism

The straining mechanism (Figs. 1 and 2) is comprised of a wheel operating a screw to which a clevis is attached. Deflection of loaded specimens is compensated by rotating the wheel, thus keeping the beam level during tests. The photographs (Figs. 1 and 2) also show the machine set up with both the pulling clevis and connecting member attached to the lever in two different positions. The clevis and connecting member may be easily shifted from one to the other of these positions, thus providing a convenient means of changing the capacity of the machine. Its maximum capacity is 1500 pounds.

Lever Combination Four lever combinations having different multiplying powers can be made, and through them a wide range of forces can be applied at the pulling clevis. These combinations will be referred to as *A*, *B*, *C* and *D* and are described in Table I. With the beam (Fig. 3) initially balanced, the removal of shot from the bucket *B* produces an upward force at *A* proportional to the weight of shot removed. The resultant force applied to the specimen at the straining clevis depends upon the lever ratios employed.

Arrangement of Spans The machine is designed so that the straining mechanism can be placed and secured at any point between the beam and lever supports (a distance of $12^1/_2$ inches), and the fixed support can be similarly shifted between points *c* and *d* (Fig. 2) on the base. This arrangement is sufficiently

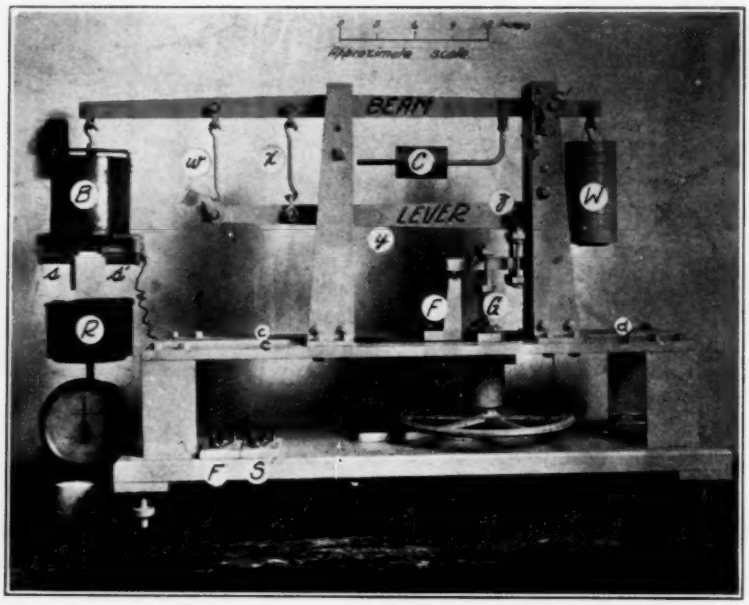

FIG. 2.—Showing lever combination of highest multiplying power.

flexible to permit the use of spans from 3 to 21 inches, a wide enough range for the usual clay and glass[1] laboratory specimens.

Adjustment of Specimens A specimen to be tested is placed through the straining clevis with its ends resting upon the fixed support and pulling clevis.[2] The pulling

[1] Williams, "The Mechanical Strength of Glazing Glass," *Jour. Amer. Ceram. Soc.*, **6** [9], 980 (1923).

[2] The straining and pulling clevis are large enough to test specimens of $2^1/_2$" x 3" cross-section.

clevis should be released (by raising the specimen slightly) and brought to rest in order to assure proper distance between the points supporting the specimen.

Operation

The beam is brought approximately to balance by pouring shot into the bucket until it is nearly equal in weight to W. A specimen is placed across the fixed support and pulling clevis, which is adjusted in the same manner described above, and the beam brought exactly to equilibrium by means of the counterpoise. Then the straining clevis is brought in contact with the specimen and the shot valve opened. The shot flowing from the bucket unbalances the beam, producing a gradually increasing active force at W which acts on the specimen and causes it to rupture; at the instant rupture occurs the valve in the bottom of the bucket is automatically closed. The beam is kept horizontal by means of the hand-wheel while the load is being applied. The weight of shot which has flowed out and which is indicated by the scale, is a measure of the force required to rupture the specimen.[1] The shot is returned to the bucket after each test and the machine is then ready for the next.

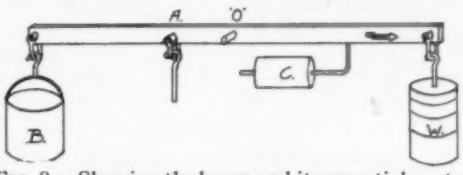

FIG. 3.—Showing the beam and its essential parts.

Calibration

As a means of calibrating the machine, a platform scale of comparatively low capacity and high accuracy replaced the fixed support. A rigid steel bar placed across the pulling and straining clevises transmitted the load to the scale, and a knife edge on the scale platform supported the fixed end of the bar. With the straining mechanism placed exactly midway between the points of support on the pulling clevis and scale, any force exerted upward by the pulling clevis was transmitted to the scale with no alteration in value. Each lever combination was calibrated by determining the respec-

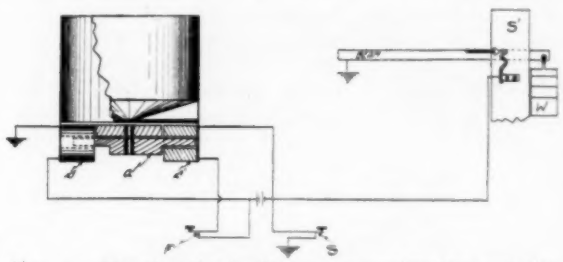

FIG. 4.—Showing the bucket, valve mechanism and electrical equipment.

[1] The dial of the scale could be calibrated to show directly the force applied at the specimen. It would be necessary to have a scale for each lever combination.

tive weights of shot required to produce each of a series of loads on the scale. The values so obtained were then corrected for the time lag of operation of the switch. This lag was determined experimentally and found to be sufficiently constant for a given load and lever combination to make this correction possible. It enables the machine to be used accurately at lower loads than would otherwise be possible. The calibration curves are not straight lines, but for higher loads they become so nearly straight lines that for all practical purposes they can be considered so.

The machine was calibrated for loads upon its straining clevis ranging from 2 to 1500 pounds. The factors limiting the maximum and minimum loads for which each lever combination was calibrated were, respectively: (*a*) time in which rupture could be expected,[1] and (*b*) the degree of accuracy obtained at small loads. Upon the same basis load limits have been recommended for each lever combination and are described in Table II. Since for high loads the calibration curve is practically straight, conversion factors (Table III) may be employed to calculate the load when the recommended limits are somewhat exceeded. However, these factors cannot be used for loads less than the maximum of the recommended ranges shown in Table III. A slight variation in the weight of shot corresponding to a definite load upon the calibrating scale was observed, but in most cases this weight was a negligible percentage of the whole, as noted in Table IV. These results apply to the apparatus under consideration only; however, they are given here to show the accuracy which is attainable with a machine of this design.

TABLE I

LEVER COMBINATIONS

Lever combination	[2] Position of		Average multiplying power	Suitable for loads from	Suitable rate of flow of shot, lbs./min.
	Connecting member	Pulling clevis			
A	*w*	*y*	7.91:1	0 to 25 lbs.	2.25
B	*x*	*y*	15.15:1	25 to 50 lbs.	4.5
B	*x*	*y*	15.15:1	50 to 150 lbs.	9.0
C	*w*	*z*	51.40:1	150 to 400 lbs.	9.0
D	*x*	*z*	99.15:1	400 to 1500 lbs.	9.0

TABLE II

RECOMMENDED LOAD LIMITS, LEVERAGE COMBINATIONS AND RATES OF FLOW OF SHOT

Load at straining clevis (in lbs.)	Leverage combination	Rate of flow of shot (in lbs. per min.)
0 to 25	*A*	2.25
25 to 50	*B*	4.50
50 to 150	*B*	9.00
150 to 450	*C*	9.00
450 to 1500	*D*	9.00

[1] The load limits recommended for each lever combination are intended to be such that test specimens will rupture in not more than $1^1/_2$ minutes.

[2] Refer to Fig. 2.

TABLE III

CONVERSION FACTORS

(Weight of shot × factor = load at straining clevis)

Leverage, combination	Shot flowed from bucket	Conversion factor
A	More than 3.3 lbs.	7.91
B[1]	More than 3.3 lbs.	15.14
B[2]	More than 13.0 lbs.	15.61
C	More than 9.0 lbs.	51.35

TABLE IV

OBSERVED VARIATIONS IN WEIGHT OF SHOT CORRESPONDING TO A GIVEN LOAD UPON THE STRAINING CLEVIS

Combination *A*			Combination *C*		
Load at straining clevis, lbs.	Variation from average		Load at straining clevis, lbs.	Variation from average	
	Maximum %	Av. %		Maximum %	Av. %
2	5.72	5.72	100	1.47	0.50
10	2.32	1.16	200	0.38	0.38
20	1.18	0.59	400	0.19	0.10
Combination *B*					
30	1.50	0.75			
40	1.13	0.57			
70	0.65	0.33			

TABLE V

LAG

Pounds shot flowed from bucket	Load at straining clevis, Combination *A*, lbs.	Overloading caused by lag, for flow of	
		9.00 lbs./min., %	2.25 lbs./min., %
0.390	3.12	21.0	5.4
0.780	6.24	7.0	1.8
1.125	9.00	3.6	0.9
1.530	12.30	1.8	0.5

TABLE VI

VITREOUS BODIES DRIED AT 100°C

(Bars approximately 1″ x 1″ x 6″; span = 5 in.)

Body no.	Lbs. shot	Load at straining clevis (in lbs.)	Modulus of rupture (lbs./sq in.)	Average, lbs.
	2.37	18.6	164	
V_3	1.67	13.0	108	
	2.45	19.4	166	139
	1.59	12.4	109	
	1.92	15.0	162	
	2.16	16.0	127	
	1.98	14.7	123	
	1.76	13.8	118	
V_4	1.74	13.7	122	121
	1.77	14.0	119	

[1] Rate of flow of shot = 4.5 lbs. per min.

[2] Rate of flow of shot = 9.0 lbs. per min.

TABLE VI (*Continued*)

Body no.	Lbs. shot	Load at straining clevis (in lbs.)	Modulus of rupture (lbs./sq in.)	Average, lbs.
	1.69	13.3	119	
V_4	1.77	14.0	126	
	1.62	12.7	105	122
	1.91	15.0	126	
	1.92	15.1	134	
	SEMI-VITREOUS BODIES DRIED AT 100°C			
	2.78	21.9	190	
	1.88	14.7	144	
SV_2	2.31	18.2	154	178
	3.01	23.9	201	
	2.64	20.9	186	
	2.92	23.2	195	
	2.41	19.0	186	
	2.49	19.6	174	
SV_3	4.38	34.5	196	182
	4.00	32.0	181	
	2.23	17.3	171	
	2.40	18.9	160	
	2.61	20.5	190	
SV_4	2.43	19.2	163	172
	2.48	19.5	165	
	2.60	20.5	169	
	2.75	21.8	185	

TABLE VII

TERRA COTTA BODY FIRED TO CONE 8

(Bars approximately 1″ x 1″ x 6″; span = 5 in.)

Lbs. of shot	Load at straining clevis (in lbs.)	Modulus of rupture (lbs./sq. in.)	Lbs. of shot	Load at straining clevis (in lbs.)	Modulus of rupture (lbs./sq. in.)
10.40	167	1415	3.66	186	1656
10.67	170	1570	3.81	193	1662
8.70	139	1208	2.73	134	1127
12.00	191	1606	3.08	155	1303
10.23	164	1425	3.63	184	1516
11.52	186	1656	4.35	221	1654
9.49	152	1355	3.30	166	1345
9.75	156	1355	3.48	176	1492
	Av.	1449[1]	3.30	177	1539
			3.42	173	1455
			3.57	182	1455
			3.30	177	1539
			3.83	194	1684
			3.86	196	1704
				Av.	1513[2]

[1] Leverage combination *B*.

[2] Leverage combination *C*.

While it is recommended that the leverage combination be used which is best adapted to the load required by specimens under test, the data in this table indicate that results are not greatly affected by using another combination.

TABLE VIII

FIRE BRICK

(Approximately $1^1/_2'' \times 2^1/_2'' \times 9''$)

Span = 5 in.			Span = 8 in.		
Lbs. of shot	Load at straining clevis (in lbs.)	Modulus of rupture (lbs. / sq. in.)	Lbs. of shot	Load at straining clevis (in lbs.)	Modulus of rupture (lbs. / sq. in.
4.96	484	1027	8.18	801	2205
10.88	1066	1854	5.40	528	1187
9.68	1046	1517	5.10	498	911
6.07	594	674	6.08	595	1552
7.88	772	1118	6.45	631	1157
8.56	839	1329	4.95	483	1382
9.53	912	765		Av.	1399
	Av.	1183			

The longer span used in this series of tests shows a higher average result and is probably due to the specimens breaking more consistently at the center.

TABLE IX

GLASS SPECIMENS (ONE SIDE SMOOTH)

(Approximately $2'' \times 0.2'' \times 20''$; span = 16 ″)

Type of specimen	Lbs. of shot	Load at straining clevis (in lbs.)	Modulus of rupture (lbs./sq. in.)	Deflection at time of rupture (in inches)
Rough on one side	2.76	21.80	5345	0.102
	2.37	18.34	4782	.103
	2.70	21.30	5635	.109
	2.10	16.45	4270	.095
	2.63	20.69	5652	.117
	2.35	18.50	4932	.103
Rough on one side	5.06	39.50	7005	.123
	3.12	24.66	3855	.059
	3.60	28.50	4985	.081
	3.48	27.64	5490	.104
Wire reinforcement	3.95	31.60	5925	.104
	6.27	49.00	7280	.119
One side corrugated	1.55	17.15	3664	.125
	4.44	34.70	4960	.074
	8.58	67.00	4700	.058
	8.82	68.90	5380	.065
	1.43	11.10	5010	.150
	1.31	10.13	4635	.127

Lag

At loads from 0 to 20 pounds (at the straining clevis) the interval of time between failure of a specimen and cessation of the shot flow becomes appreciable. The effect of this lag may be offset by reducing the rate of flow of shot until the

product of the lag and rate of flow becomes a negligible fraction of the total load. The lag at various loads between 0 and 20 lbs. was computed and its effect at two rates of flow is shown in Table V. The large differences found clearly indicate the necessity for applying small loads very slowly.

Results

Tables VI to IX, inclusive, contain results representing the machine's performance.

Other Appliances

The machine is also adapted to determining deflection of specimens under definite loads. The screw to which the pulling clevis is attached was calibrated with an Ames Gage and found to have a pitch of .05 inch. To determine the vertical travel of the screw and clevis the perimeter of the wheel which operates them was graduated in 50 divisions. This graduation furnishes a means of counting the number of revolutions of the wheel required to keep the beam horizontal while loading a specimen and, therefore, a means of determining the deflection of the loaded specimen. To observe deflections under predetermined loads, the flow of shot can be stopped when desired by means of the spring contact S (Fig. 4).

TABLE X
CORRECTIONS FOR MACHINE DEFLECTION

Loads (pounds)	Corrections (inches)	Loads (pounds)	Corrections (inches)
0 to 50	0.000	600 to 650	0.013
50 to 100	.002	650 to 700	.014
100 to 150	.005	700 to 750	.015
150 to 200	.006	750 to 800	.016
200 to 250	.007	800 to 900	.016
250 to 300	.008	900 to 1000	.018
300 to 350	.009	1000 to 1100	.020
350 to 400	.009	1100 to 1200	.022
400 to 450	.010	1200 to 1300	.023
450 to 500	.010	1300 to 1400	.025
500 to 550	.011	1400 to 1500	.027
550 to 600	.012		

Deflection in the machine itself becomes appreciable when loads greater than 50 pounds are applied to the straining clevis. Table X, compiled from experimental results, contains corrections which apply within the indicated load limits, and which must be subtracted from the values observed when measuring deflections. No error greater than .002 inch will be introduced by using this table, but each machine must be calibrated individually as the tabulated values refer to this one only.

In order to determine the deflection in the machine, the span was reduced to 3 inches and a steel bar ($1^1/_2$ x 3 x 4 inches) placed across the

straining mechanism as a specimen; the bar was loaded at successive intervals of 1.5 lbs. of shot, from 0 to 15 lbs., for each lever combination, and the deflection observed for each load.

Advantages

1. Sensitivity and elimination of the personal element by automatic operation make it possible to obtain accurate results.

2. Adjustment to different spans and lever ratios is easy, and this feature is of importance where a large variety of specimens are to be tested.

3. The simple and rugged construction of the machine insures consistent, dependable service.

THE EFFECT OF HEAT ON THE STRENGTH OF CALCINED KIESELGUHR-PORTLAND CEMENT MIXTURES[1]

By Samuel J. McDowell and Hobart M. Kraner

ABSTRACT

The effect of heat upon the strength of this material is shown. This decreases rapidly at 100°C and remains fairly constant between 200° and 500°C. It decreases until 800° where a slight increase is shown between this and 1000°C. Above this the strength decreases.

Introduction

In certain types of ceramic construction it is highly desirable to use flat slabs which must at least bear their own weight. Very often they are not subjected to extremely high temperatures and a certain amount of heat insulation is desired. For a slab of this kind the monolithic tamped block of calcined kieselguhr grain ("C-3" material sold by the Celite Products Company) and Portland cement suggests itself.

In an endeavor to ascertain the effect of heat on the ability of such a slab to support its own weight or an additional weight, the following experiments were conducted.

Materials

Calcined Kieselguhr or "C-3" Material This was California kieselguhr which had been calcined to 1200°C and in which a volume shrinkage of approximately 25% had taken place due to this firing. The screen analysis of this material as used in these experiments was as follows:

Total residue on	Per cent
4-mesh	0.0
6-mesh	33.3
8-mesh	35.7
12-mesh	47.4
30-mesh	65.2

Portland Cement This was Huron Portland cement made by the Huron Portland Cement Company of Alpena, Mich. Analyses[2] and tests[2] made on the cements used were as follows:

Chem. anal.	
SiO_2	20.30
Al_2O_3	6.04
Fe_2O_3	2.96
CaO	62.50
MgO	2.24
SO_3	1.52

Fineness	
17.2% retained on 200-mesh	

Setting time	
Initial set	4 hours 40 minutes
Final set	7 hours 30 minutes

[1] Recd. Aug. 14, 1925.

[2] Made through the courtesy of the Huron Portland Cement Company.

Tensile strength, neat cement	Lbs. per sq. in.
24 hours	400
24 hours	415
7 days	720
7 days	710
7 days	660
28 days	760
28 days	795

Preparation of Test Pieces

A mixture of four parts "C-3" and one part Portland cement by volume is recommended by the Celite Products Company for furnace door backing

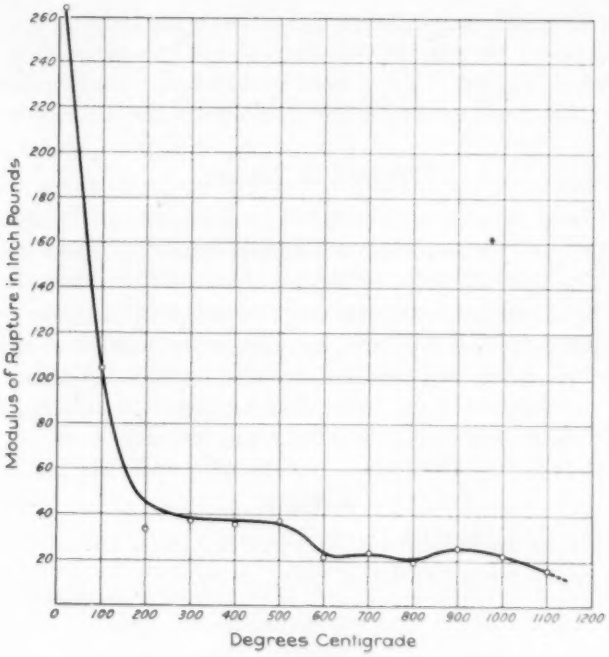

FIG. 1.

and foundation construction. This proportion which is the same as 55% "C-3" and 45% Portland cement, by weight, was used.

The cement and "C-3" material were thoroughly mixed dry by hand. Sixty-five per cent, of this dry weight, of water was then added and the whole again mixed. This gave good tamping or forming consistency which is similar to that used in forming pressed cement blocks.

The damp mixture was pressed by hand into a mold 2 x 2 x 10 inches. The top and bottom of the bars were smoothed with a spatula. They

were kept covered with a damp cloth for two days and then allowed to age in air for 28 days.

In order to get an average from as large a number of pieces as possible, and to minimize the differences due to this method of forming, three batches were made up and bars from each followed through separately.

Method of Heating

Two bars from each batch were heated side by side to each temperature in a small electric laboratory nichrome resistance furnace. In order that the heating might be as uniform as possible, the bars were placed in the furnace on three supports instead of being placed on the bottom of the furnace. The temperature was raised at the rate of 100°C per hour until the desired temperature was reached. After being held at this temperature for four hours, the current was shut off and the pieces allowed to cool in the furnace overnight. They were broken each morning immediately upon being taken from the furnace to avoid possible rehydration.

Method of Testing

The bars were broken as 8-inch beams with the load applied at the middle of the span. One-half inch diameter round iron bars were used as supports. The test bars were broken on their sides; that is, the load was applied at right angles to the direction of pressing into the mold when formed. This gave two flat sides parallel with each other made so by the sides of the mold, and which were most suitable as bearing surfaces in testing. Testing on these sides also somewhat minimized the effect of irregularities of structure caused by hand forming.

Results

The modulus of rupture of the bars was determined from the following formula. Results are indicated in inch-pounds.

$$\frac{3Pl}{2bd^2}$$

where P = breaking load in pounds; l = length of span in inches; b = width of bar in inches; d = depth of bar in inches.

	Batch 1		Batch 2		Batch 3			
Temp., °C	Bar A, lbs. to break	Bar B, lbs. to break	Bar A, lbs. to break	Bar B, lbs. to break	Bar A, lbs. to break	Bar B, lbs. to break	Av. lbs. to break	Modulus of rupture
Room temp.	206	222.75	161	145	207	122	177.2	265.8
100	70	82.75	84.25	42	72	lost	70.2	105.3
200	29.9	16	13.25	22	27.5	26.5	22.5	33.8

300	33	27.25	20.25	13.5	24	30.5	24.7	37.1
400	23.75	20.5	20	32	16	30.6	23.8	35.7
500	21	28.5	9.5	5.25	44	40	24.7	37.1
600	17.25	13	8.25	9.4	21.5	15.5	14.2	21.3
700	4.5	13.6	11.5	14.25	33	13	15.0	22.5
800	9.9	8.6	7	10	19.25	20	12.5	18.8
900	19	13.5	13.5	10.75	20	23	16.6	24.9
1000	21.1	20.4	7.75	12.75	7.5	17	14.4	21.6
1100	9.75	14.25	4.5	8.1	23.75	broke in furnace	10.1	15.2

The differences in strengths of the different batches indicate differences in forming conditions although efforts were made to keep the conditions the same.

Figure 1 shows moduli of rupture of these mixtures after heating to the temperatures indicated.

Conclusions

The foregoing results indicate:

(1) Great decrease in strength between room temperature and 100°C. This might be accounted for by a partial dehydration of the cement at this temperature although S. F. Newberry[1] states that this dehydration starts at 400°F (204°C) and is complete at 900°F (482°C).

(2) That the strength remains practically constant between 200°C and 500°C. The adhesion between the "C-3" and the cement is so great that in these bars heated below 500°C the fracture is through the "C-3" grains rather than at their surfaces.

(3) A sharp decrease in strength between 500°C and 600°C.

(4) That the strength remains practically constant between 600°C and 900°C.

(5) That there is a slight increase in strength at 900°C and 1000°C This is probably due to initial sintering.

(6) That there is a rapid decrease in strength above 1000°C. Further sintering or melting around the grains causes a decided change in structure. The light siliceous "C-3" material is dissolved by the glass which is formed at these temperatures. This glass occupies so much smaller volume that the particles no longer have contact and the result is a weak structure.

From the results of these experiments and actual experience with this material in a more practical way, the following are recommended for tamping large monolithic slabs:

(1) Great care should be taken to avoid structural defects so that no planes of weakness develop between the various layers in the tamped

[1] *Concrete*, May, 1902.

block. Each batch should be tamped as soon as possible after mixing and each layer should be sprinkled slightly with water before a fresh layer is put in.

(2) The use of steel or iron reinforcement is not recommended due to the structural defects which develop and also to the fact that oxidation of the steel bar will disrupt the slab on account of its slightly increased size caused by oxidation.

It is not the desire of the writers to set forth this material as one which will satisfy all conditions, but rather to show that it is effective up to a definite temperature and that it has a decided value in ceramic construction.

A.-C. SPARK PLUG CO.
FLINT, MICH.

CERAMIC ABSTRACTS

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Vol. 4 **November, 1925** **No. 11**

Author Index[1] to Ceramic Abstracts for September

AUTHOR	PAGE
Amsler, W. O.	300
Arthur, E. P.	300
Atkinson, J. S.	301
Bacon, R. H.	323
Bangham, D. H. and Burt, F. P.	302
Belani, E.	323
Bennett, J.	306
Biehl, C.	299
Bingham, E. C.	321
Bleininger, A. V.	321
Bøggild, O. B.	322
Bowman, J. D. and Roth, T. J.	314
Brown, E. C. and Partington, J. R.	322
Buckley, F.	301
Bull, W. C.	306
Burger, M.	313
Chamberlin, B. D.	304, 305
Chow, M. C.	299
Cousen, A. and Turner, W. E. S.	301
Cownshaw, Mather, J. C. & Platt, Ltd.	303
Crow, W. and Schaffer, J. C.	312
Dale, A. J.	308, 309, 310
Damiens, A.	322
Darby, G. M.	314
Delacuvellerie, E.	306
Demolon, A.	322
Drake, R. W.	323
Dressler, C.	299
Drummond, J. G.	319
Dyckerhoff, W.	298
Ellersick, K.	307
English S.	300
Eurich, H., W. and A. and Nitzsche, H.	299
Fitch, W. H.	315
Forsythe, W. E.	315
Fosseen, A. B.	314
Funa, K.	303
Geller, R. F.	311
Gmelin, P.	321
Grauel, A.	306
Greene, R. J.	314
Grupp, C.	312
Guelle, A. M.	323
Gumz, W.	319
Hadding, A.	318
Hanford, O. A.	305
Hardwick, C. W.	308
Harris, F. C.	303
Headley, B. T., DuBois, D. I. and Fennimore, W. C.	304
Heal, W. E.	307
Heath, F.	309
Heffron, J. F.	303
Helberger, H.	312
Higman, J. W.	312
Hill, J. B., Nichols, L. W. and Cowles, H. C.	319
Hirsch, H. and Pulfrich, M.	320
Holmes, M. E. and Fink, G. J.	299
Holmquist, P. J.	322
Houldsworth, H. S.	310
Howard, G. E.	307
Hudler	322
Hugill, W. and Rees, W. J.	318, 319
Hull, W. A. and Ingberg, S. H.	298
Ivens, W. H.	313
Jordan, R.	311
Karrer, E. and Poritsky, A.	315
Kirch, T. E.	300
Klose, E.	316
Kreger, J. M.	313
Luce, G. E.	308
McDougal, T. G.	317
McElroy, K. P.	311
Mauder, B.	324
Mekler, L. A.	317
Meyer, P.	301
Morison, C. G. T.	319
Noble, O. C.	305
Olsen, J. C., Lindenthal, W. and Sherman, I.	315
O'Neill, F.	304
Parkert, O.	301
Pfaff, A. and Rath, W.	312
Pike, P. R.	306
Plant, H. J.	312
Poetschke, P.	299
Power, H. R.	298
Preble, J. J.	316

[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from *Chemical Abstracts* by coöperative agreement.

Author Index to Ceramic Abstracts for September (*Continued*)

Author	Page
Radeff, K.	299
Rees, W. J.	310, 311
Rhead, T. F. and Jefferson, R. E.	309, 310
Rhoads, T. H.	316
Saint, L. B.	300
Sanford, A. J. and Townsend, J. B.	307
Schieldrop, B.	324
Schnurpfeil, H.	306
Scholes, S. R.	303
Seldon, H. W.	324
Shively, R. R.	305
Singer, F.	324
Slagle, E. A. and Feltz, A.	313
Springer, L.	301
Stacey, A. E., Jr.	315
Staley, H. F.	299
Stow, C. M.	300
Strauss, B.	301
Thomason, W.	299
Treischel, C. C.	313
Turner, W. E. S.	301, 303
Turner, W. E. S. and Winks, F.	302
Twyman, F.	315
Vernadsky, W.	318
Vickers, A. E. and Theobald, L. S.	309
Wataya, M.	313
Wayringer, H. A.	304
Weigel, W. M.	299
Wilcox, A. C.	304
Willmer, H.	317
Wintermeyer, F.	322
Zschimmer	303

Abrasives

PATENT

Binder composition for abrasives and other materials and method of making same. HENRY R. POWER. U. S. 1,553,105, Sept. 8, 1925. The method of making a cement compn. which comprises forming a cement mixt. contg. calcium hydrate and subjecting the mixt. to the action of carbonic acid gas to thereby convert the calcium hydrate into a calcium carbonate.

Art

How Palissy, poor village geometer, became world famous potter. ANON. *Pottery, Glass & Brass Salesman*, **32** [2], 15(1925). (Told in "The Penny Magazine" in 1847).—An account of the 15 yrs. of expts. against incredible odds which led to his final perfection of porcelain. F. G. J.

Cement, Lime and Plaster

Cement industry in Australia. ANON. *Jour. Soc. Chem. Ind.*, **44**, 820(1925).—The works of the Standard Port. Cement Co. at Kandos, New South Wales, which adjoin the works of the Kandos Cement Co. will shortly be completed to meet the ever increasing Australian demand. H. H. S.

Fire resistance of concrete columns. W. A. HULL AND S. H. INGBERG. Bur. of Standards, *Tech. Paper* **272.**—The study of the fire resist. of concrete columns included fire tests of 62 columns under working load and compression tests of 16 comparable columns not subjected to fire tests. A few columns were of plain concrete, others had vertical reinforcement inside of lateral reinforcement in the form of spirally wound wire, as is now generally used where heavy loads are supported. H. F. S.

The processes in firing synthetical raw flour. WALTER DYCKERHOFF. *Zement*, **14**, 174–7(1925).—A mixt. of CaO, SiO_2 and Al_2O_3 analogous to Port. cement which was heated according to the methods used by the technician after firing consisted of about $^2/_3$ of β-bicalcium silicate enriched by CaO which is absorbed to a considerable amt. in solid soln., furthermore of tricalcium aluminate, pentacalcium trialuminate and very little CaO. The unstable β-bicalcium silicate fixed by the final melting and enriched by CaO is the carrier of the hardening. The fixation of the unstable modification is the main part of the problem of mfg. binding agents able to harden. The quality of the cement depends in the first place upon absorbing lime in solid soln. By quick cooling this solution is also stable. W. S.

Contribution to the petrography of the modern Portland cement clinker. CARL

BIEHL. *Zement*, **14**, 379–82, 397–9(1925).—By microscopical investigation of the clinker it is possible to draw conclusions as to firing, sintering, kind of kiln, cooling, influence of fluxes, chem. compn. and quality of the cement made of that clinker. Clinkers with good and rich crystal formation (alite) were produced by high fire and influence of flux. The best cements are obtained from sudden cooled clinkers, where a complete crystn. of the minerals is prevented and a storage of energy in the glass is reached which becomes effective in cooling. W. S.

The hydration of high calcium aluminates. KRISTO RADEFF. *Zement*, **14**, 177–82 (1925).—Hydration of tricalcium aluminate results in tricalcium hydro aluminate, that of monocalcium aluminate and pentacalcium trialuminate is tricalcium hydro aluminate if there is sufficient lime for its formation. In hydrating the compn. $4CaO.Al_2O_3$ lime is given off. There were no marks that proved the presence of a tetra calcium hydro aluminate. Alumina hydrate combines with calcium hydrate to crystallized aluminate. The aluminates tend to form the ratio $1CaO:3Al_2O_3$. W. S.

The importance of the sulphates of slag on the durability of the slag products and on their behavior with changing humidity. H., W. AND A. EURICH AND H. NITZSCHE. *Zement*, **14**, 338–40, 358–63, 389–90(1925).—According to thorough investigations it is recommended to limit the contents of sulphates to 1% $CaSO_4$ and 2% other sulphates, and to work with refrac. cement if a higher content of sulphates cannot be avoided. W. S.

PATENTS

Dental cement and process of making same. PAUL POETSCHKE. U. S. 1,552,341, Sept. 1, 1925. A dental cement powder comprising a compd. composed of acid sol. calcined zinc silicate. A dental cement powder comprising a compd. composed of calcined zinc silicate and calcium fluoride. The process of producing a dental cement powder which comprises calcining pptd. zinc silicate to form a compd. which is decomposable by phosphoric acid to yield a colloidal jelly.

Production of quick-setting lime products by the addition of an aluminum fluoride. MAJOR E. HOLMES and GAIL J. FINK. U. S. 1,554,183, Sept. 15, 1925. A plastic mat. having quick initial setting properties comprising hydrated lime and an aluminum fluoride.

Production of quick-setting lime products by the addition of zeolites. MAJOR E. HOLMES and GAIL J. FINK. U. S. 1,554,184, Sept. 15, 1925. A plastic mat. having quick initial setting properties comprising hydrated lime and a zeolite.

Enamel

Turning a poor enameling furnace into a good one. HOMER F. STALEY. *The Ceramist*, **5** [3], 144–9(1924).—By converting an inefficient closed muffle type fur. into a semi-muffle type fur. 70–75% fuel saving was accomplished. Data and diagrams are given. A. E. R. W.

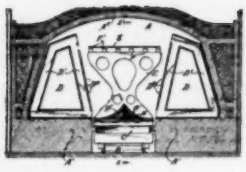
Special sands. W. M. WEIGEL. *The Ceramist*, **5** [3], 177–83(1924).—Portions of interest to ceramists of Bur. Mines Repts. of Invest. No. 2615—"Sand Blast Sand," and No. 2622—"Filter Sand for Municipal Water Supply" (1924). A. E. R. W.

The porcelain enameling of iron castings. WM. THOMASON. *Ind. Chemist*, **1**, 273–6(1925).—A review. (*C. A.*)

Research on enamel raw materials. M. C. CHOW. *J. China Soc. Chem. Ind.*, **3** [1], 9–38(1925).—Analyses. (*C. A.*)

PATENT

Method of and apparatus for enameling. CONRAD DRESSLER. U. S. 1,552,475, Sept. 8, 1925. The method of enameling both sides of flat articles in a tunnel kiln



of the muffle type by means of a convection current circulation of the kiln chamber and radiant heat, which consists in supplying heat at substantially the same rate to each side of the article by setting up a convection current circulation of the kiln atmosphere in directions transverse to the length of the kiln while holding the articles in a horizontal position in the kiln chamber with their upper sides exposed to radiant heat from the roof of the kiln and their lower sides exposed to radiant heat from the hot kiln walls at the sides of, and beneath, the articles.

Glass

The cost of melting glass by fuel oil and coal. T. E. KIRCH. *Nat. Glass Budget*, **41** [7], 10(1925).—Lists the equipment needed for each type of fuel and the items contributing to operation costs. Not only the cost of the fuel and its calorific value must be considered but also the first cost and the operating cost. F. G. J.

Old stained glass. L. B. SAINT. *Nat. Glass Budget*, **41** [15], 3(1925).—An address at the annual meeting of the Stained Glass Manufacturers Assn. F. G. J.

Glass Container Association takes up statistical work. ANON. *The Glass Worker*, **44** [46], 17(1925).—At their convention they inaugurated a statistical department and adopted the slogan "See what you buy—buy in glass." F. G. J.

Winslow Glass Company prepares to operate new unit. E. P. ARTHUR. *The Glass Worker*, **44** [48], 17(1925).—A description of a thoroughly modern milk bottle factory to be opened at Columbus, Ohio, about Sept. 1. F. G. J.

Dunbar Flint Glass Corp. soon to operate addition. ANON. *The Glass Worker*, **44** [49], 17(1925). F. G. J.

Performance of glass melting tanks. W. O. AMSLER. *The Glass Worker*, **44** [49], 19(1925).—Reprinted from *Fuels and Furnaces*. F. G. J.

World's largest Fourcault system factory. ANON. *The Glass Worker*, **44** [47], 19(1925).—A 12-mach. plant, under construction for two years, will soon start at Zeebrugge, Belgium. F. G. J.

Old Sandwich glass designs. CHARLES M. STOW. (From the *Boston Transcript*.) *Pottery, Glass & Brass Salesman*, **32** [1], 13(1925).—The celebration of the 100th anniversary of the opening of the famous glass works founded by Deming Jarves includes, besides a loan exhibition of products, a book of drawings of patterns of epergnes, lamps and vases and a notebook of formulas for making color stain in Deming Jarves' own handwriting. F. G. J.

The effect of composition on the viscosity of glass. III. Some four-component glasses. S. ENGLISH. *Jour. Soc. Glass Tech.*, **9** [34], 83–98(1925).—With a soda-lime glass as a starting point, mol. quantities of (1) magnesia and (2) alumina replaced mol. quantities of lime thus giving a series of 4 component glasses in each of which the relative mol. quantities of sodium oxide and silica remained constant. The detn. of the viscosities of these glasses was carried out through the lower and higher ranges of temps. in exactly the same way as described in Pts. I and II of this paper (*Ceram. Abs.*, **4** [1], 5; **4** [3], 63). At temps. 1300°C to 1400°C magnesia substituted for soda in sodium trisilicate, causes a greater increase in viscosity than does a mol. equivalent quantity of lime. At temps. 1400–800°C the viscosities of soda magnesia silicates increase at more uniform rates than do the corresponding soda-lime glasses. Substitution of alumina for lime caused an increase in viscosity at 1200°C and 1400°C but up to 0.1 alumina at 1000°C and 800°C caused a decrease in viscosity. Magnesia substituted for lime up to 0.40 mol. caused a decrease in viscosity from 800–1400°C. R. M. K.

Glasshouses on the Wear in the eighteenth century. FRANCIS BUCKLEY. *Jour. Soc. Glass Tech.*, **9** [34], 105–11(1925).—The names and a short history and description of glasshouses on the Wear in the 18th Century are given. R. M. K.

A note on the changes of color of selenium glasses during annealing and reannealing and by exposure to light. A. COUSEN AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **9** [34], 111–7(1925).—Samples of yellow and pink soda-lime glasses contg. small quantities of selenium were heated in an elec. fur. at 25° temp. intervals 500–625°C. Samples were also exposed to light for 13 months. Conclusions are that final color depends on starting color, and temp. and time of annealing. Colorless glasses remain colorless, yellow remain yellow, and pink tend to yellow on htg. Effect of exposure to light essentially reverse of the effect of htg. R. M. K.

The production of colorless glass in tank furnaces with special reference to the use of selenium. III. The influence of arsenious oxides and other constituents of the batch. ARNOLD COUSEN AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **9** [34], 119–27 (1925).—Attention is called to contents of the previous paper (*Ceram. Abs.*, **4** [2], 34 (1925)). The effect of arsenious oxide as a decolorizing agent was tried out on a glass (batch: sand 1000, soda 370, limespar 300) both in the presence of selenium and in its absence. Temp. and duration of melting were carefully controlled. Results show arsenious oxide to be a necessary factor in decolorizing glass with selenium. Amt. of arsenious oxide is governed by the time and temp. The minimum should be 30 times amt. selenium. Arsenious oxide is itself a decolorizer. Antimony oxide or calcium phosphate are not satisfactory substitutes for arsenious oxide. Rules for the control of pink color in glass are given. R. M. K.

Some notes on improvements in gas producers. J. S. ATKINSON. *Jour. Soc. Glass Tech.*, **9** [34], 127–32(1925).—Attention is called to the fact that Chapman Automatic Gas Producers in use were proving to be a success. A half-tone of a cross section of this producer is shown and its outstanding mech. features are described. Some analyses of gas from such a producer are given. Its chief advantages are listed as follows: (1) It has no heavy moving parts; only those doing the work are moved; (2) first cost is lower than other producers; (3) it is simple in operation; (4) the rate of gasification is high; (5) the rate of ash removal is uniform and thus aiding in producing a uniform fuel bed and uniform quality of gas; (6) the upkeep is low. R. M. K.

An attempt to improve the qualities of glasses intended for lamp-working purposes. W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **9** [34], 133–47(1925).—This article deals with expts. to improve alkali-lime glasses for surgical purposes. Compns. of glasses worked with are given. These glasses were tested for melting and working properties, and for durability. Practical lamp-working tests were made. Tables give data regarding the properties studied. R. M. K.

Materials used in the glass industry. B. STRAUSS. *Diamant*, **47** [22], 443(1925).—A discussion of various alloys as substitutes for cast iron for making molds. F. G. J.

Recovery of waste heat from glass furnaces. P. MEYER. *Diamant*, **47** [22], 445(1925).—Not much progress has been made as compared with the steel industry. F. G. J.

Development and investigation of faults in glass. L. SPRINGER. *Diamant*, **47** [22], 445(1925).—Describes and explains the typical faults. F. G. J.

The development of matt and reflecting iridescence on glassware of all sorts. O. PARKERT. *Diamant*, **47** [23], 467(1925).—Formulas are given. F. G. J.

Cement for chemical glasses to stand fire. ANON. *Oil & Color Trades Jour.*, **68**, 726(1925).—Mix equal quantities of wheat flour, fine powdered Venice glass and pulverized chalk with half the quantity of fine brickdust and a little scraped lint in white of

egg. This mixt. is to be spread upon a linen cloth and applied to the cracks of the glasses, and should be well dried before put into the fire. O. P. R. O.

Glass industry in Belgium. ANON. *Jour. Soc. Chem. Ind.*, **44**, 799(1925).—A new glass works, which covers an area of 17 acres at Zeebrugge, will begin production shortly. Some 3000 workmen will be employed, an industrial town having been built to accommodate them. H. H. S.

Sorption of nitrous oxide and sulphur dioxide by glass. D. H. BANGHAM AND F. P. BURT. *Jour. Phys. Chem.*, **29** [5], 540–50(1925).—Expts. on the sorption of nitrous oxide and sulphur dioxide by a glass surface at 0°C. The glass surface used was a tube of glass wool. The expts. were carried out at a series of pressures ranging from 44 mm. to 640 mm. Observations extended from 52 seconds to 5 days. Summary: The sorption of nitrous oxide by glass reproduces the essential characteristics observed with carbon dioxide, considering any series of const. press. expts. log (sorption) appears to be a single valued function of log ($p^{.6}$·^{6}t) the relationship approximating more closely to the linear than in the case of CO_2. Sulphur dioxide also follows the linear log (sorption) log (time) law, but as it was impossible to out-gas the sorbent the pressure exponent was not detd. E. J. T.

Boric acid in chemical-resisting glass. W. E. S. TURNER AND F. WINKS. *Chem. Age*, **12** [315], 629(1925).—It was found generally that the introduction of boric oxide reduced the thermal expansion of the glass and also increased the durability of a glass against the action of water and neutral solns. and, to a certain extent, against acids. It was found from tests that the use of boric oxide had very definite limitations and that when the amt. of boric oxide added to a glass was beyond a certain percentage its value began to disappear and was in some proportions exceedingly detrimental. Tests showed the max. advantage was obtained with between 11 and 14% boric oxide and, in the case of more complicated glasses, between 10.6 and 13.6%. In a paper by the same author on an attempt to improve the working qualities of glass intended for lamp-working purposes glasses of the following compn. were found best:

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	B_2O_3
66.74	5.48	0.07	6.16	1.18	5.10	14.60	0.40
68.16	4.27	0.06	6.48	0.71	5.32	14.57	0.22

E. J. T.

Boric oxide as a constituent of laboratory glass. ANON. *Chem. Age*, **12** [306], 403(1925).—A discussion of some of the properties of glasses contg. boric oxide, such as lowering of the coeff. of expansion, resistance to thermal and mechanical shock and resistance to attack by acids. E. J. T.

The constitution of glass. A LONDON SYMPOSIUM. *Chem. Age*, **12** [311], 527 (1925).—A brief résumé of the papers presented at the May meeting of the Society of Glass Technology which included: "Glasses as Supercooled Liquids," by G. Tammann; "The Constitution and Density of Glass," by A. Q. Tool and E. E. Hill; "The Ternary System Sodium Metasilicate Calcium–Metasilicate–Silica," by G. W. Morey and N. L. Bowen; "Thé Viscosity and Allotropy of Glass," by H. L. Chatelier; "The Structure of Quartz and Silica," by Wm. Bragg; "X-Ray Studies of Soda-lime-silica Glasses," by G. W. Morey and R. W. G. Wyckoff; "The Viscosity of Glass," by V. H. Stott. E. J. T.

Society of Glass Technology papers at Newcastle meeting. ANON. *Chem. Age*, **12** [303], 333(1925).—(*a*) The use of zirconia in glass making and the characteristics which this substance imparts are discussed. The glasses contg. considerable amts. of zirconia were difficult to melt and were viscous like alumina glasses but with a shorter working range than the latter. The zirconia glasses did not exhibit low thermal expansion. Their annealing temps. increased with zirconia content less steeply than correspond-

ing glasses with basic oxides such as lime and magnesia. Replacement of silica by zirconia increased the resistance to alkaline solns. (*b*) The second paper was on the effect of compn. on the viscosity of glass by S. English. As a starting point a glass of mol. compn. 1.2 Na_2O, 0.8 CoO, 6 SiO_2 and lime substituted by magnesia which lowered the viscosity, and caused the rate of increase of viscosity with falling temp. to become more uniform. E. J. T.

Modern production of sheet glass. W. E. S. TURNER. *Jour. Roy. Soc. Arts*, **73** [3792], 821–37(1925).—A lecture describing the modern methods of glass manuf. including tables giving the production of glass in this country and abroad, showing Belgium to be the leading exporter of glass in Europe. E. J. T.

Tank block essentials. S. R. SCHOLES. *The Ceramist*, **5** [2], 92–5(1924).—S. specifies the properties that should be exhibited by tank blocks to meet the requirements of modern practice. Discusses (1) refractoriness, (2) insoly., (3) low porosity, (4) mech. perfection. A. E. R. W.

Theories advanced in reference to the effect of cullet in glass batches. R. R. SHIVELY. *The Ceramist*, **5** [4], 235–7(1925).—An increased amt. of cullet gives a "stiffer natured" glass. This is attributed by some to an increase in viscosity due to the slightly different composition of the cullet, by others to the cullet's lower content of dissolved gases. S. advocates the mixing of crushed cullet and batch, and condemns the use of cullet from unknown sources. A. E. R. W.

Annealing of glass. R. R. SHIVELY. *The Ceramist*, **5** [5], 274–8(1925).—S. deplores the general tendency to increase production without increasing leer capacity. For perfect annealing, the glass should be heated to the upper annealing temp. and then cooled slowly to the lower annealing temp. The annealing temp. increases as soda content decreases and lime content increases. The effect of other oxides on annealing temp. is given. S. recommends leers closed at both ends and not over 9 ft. in width. A. E. R. W.

Coloring glass by means of nickel. KITSUZO FUNA. *J. Japan. Ceram. Assoc.* No. **361**, 430–44(1922); *Chimie et industrie*, **13**, 99.—NiO gives a purple color to K glass and a brown color to Na glass, the color losing clearness when the quantity of Ni oxide is increased. The bivalent element which enters into the compn. of the glass has little effect, except Ba, which acts on the color. In borosilicates NiO gives a purplish pink. Oxidizing (KNO_3) or reducing agents (K tartrate or As_2O_3) do not interfere with the production of the color. (*C. A.*)

The photo-elastic constants of glass as affected by high temperatures and by lapse of time. F. C. HARRIS. *Proc. Roy. Soc.* (London), **106A**, 718–23(1924).—The stress-optical coeff. shows an increase with rise of temp. with the exception of an extra dense flint (PbO = 64.4%). Twelve glasses tested also showed an increase with lapse of time. (*C. A.*)

Perfume, the fragrance of femininity. ANON. *Glass Container*, **4** [10], 5–7 (1925).—Points out the desirability of artistic effects in perfume bottles, with illustrations. W. M. C.

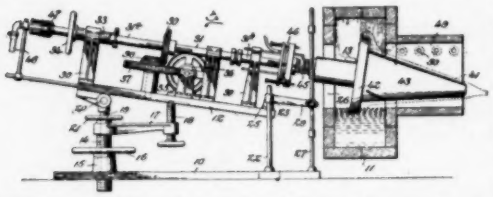
History of glass making. Roman glass. J. F. HEFFRON. *Glass Container*, **4** [10], 14–22(1925).—Descriptive article well illustrated. W. M. C.

Glass as a raw material in illuminating engineering. ZSCHIMMER. *Glastechn.*, **1**, 73–6(1923); *Chimie et Industrie*, **11**, 930(1924).—An address on the properties and qualities required of glass used for illumination purposes. W. M. C.

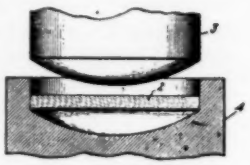
PATENTS

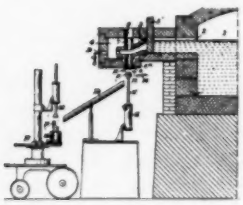
Glass bulbs. Glass manufacture. COWNSHAW, J. C. MATHER & PLATT, LTD. Brit. pat. 213,375(1923). A device for blowing small bulbs on capillary tubing using a cylinder with a sliding piston. A very simple device.

Glass-working apparatus. ALBERT C. WILCOX. U. S. 1,550,995, Aug. 25, 1925. In glass working app., a rotatable member having an inclined surface over which molten glass is adapted to flow continuously towards one end of the member, and means included in said member at its other end to elevate molten glass continuously from a supply and deliver it to said surface.



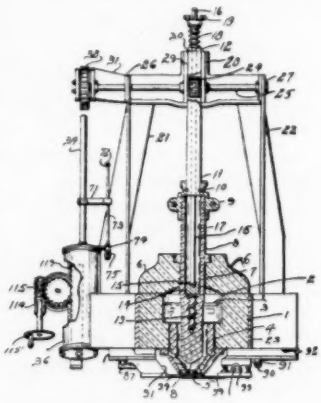
Process of forming quartz articles. HENRY A. WAYRINGER. U. S. 1,551,351, Aug. 25, 1925. The method of mfg. quartz articles which consists in casting fused quartz into the form of a mass having a cross-section substantially equal to the cross-section desired in the finished articles, mechanically subdividing said mass when solidified into sections, reheating said section to a temp. of plasticity and molding to a desired form.

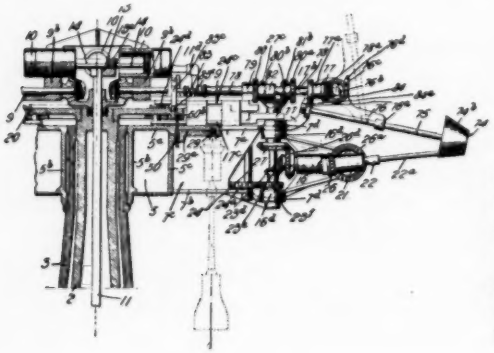




Method and apparatus for feeding glass. BENJAMIN T. HEADLEY, DAVID IRVIN DU BOIS and WILLIAM C. FENNIMORE. U. S. 1,551,513, Aug. 25, 1925. A glass-working app., comprising a feeder cup adapted to contact with a stream of glass, means for operating said feeder cup to maintain the same in contact with said stream for a predetd. length of time and subsequently increase the speed of movement of the cup to withdraw the cup from such supporting contact, means for severing the stream to form a gather, means for engaging the gather to move the same laterally, and a trough for receiving and conveying said gather, substantially as described.

Glass-feeding apparatus. FRANK O'NEILL. U. S. 1,551,526, Aug. 25, 1925. In the feeding of molten glass from a pool, a plunger, a cylinder including connections for operating the plunger, said cylinder being mounted to have its axis extend at an angle to the axis of the plunger, and an adjustable mounting for shifting the cylinder along its axis.

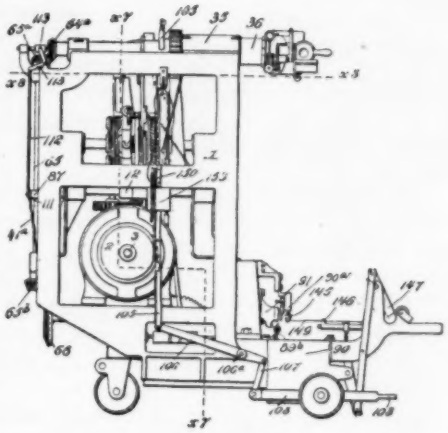




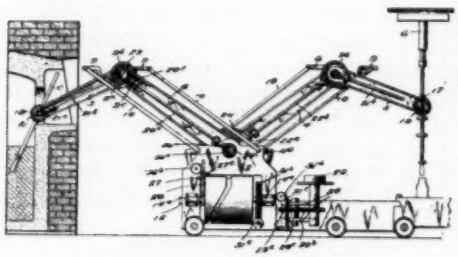
Glass-working machine. BENJAMIN DAY CHAMBERLIN. U. S. 1,551,934, Sept. 1, 1925. In a glass-working mach., the combination with a support for a glass-carrying spindle, of a rotating marverer, successive points of which are brought into contact with the glass

on the rotation of the marverer, which points are successively closer to the axis of the spindle, and means for rotating the spindle.

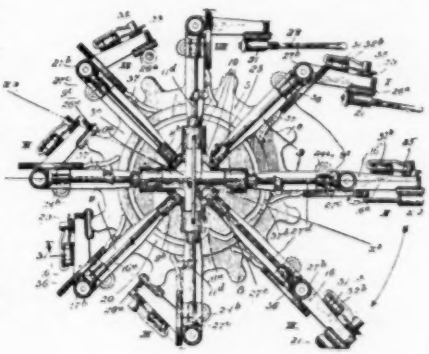
Machine for producing blown-glass articles. ORIN A. HANFORD. U. S. 1,551,936, Sept. 1, 1925. In a glass blowing mach., the combination with a movable blowpipe having several operative positions, of a separable mold, means for moving the blowpipe in respect to the mold from one of said positions into another of said positions for elongation of the gather thereon and to present the gather to the mold, and means for automatically closing the mold.



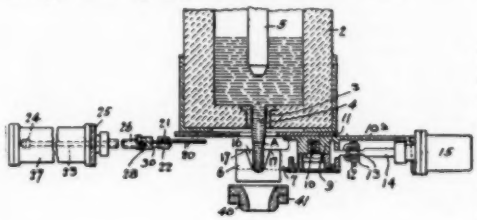
Apparatus for gathering glass and the treatment thereof on blowpipes. BENJAMIN D. CHAMBERLIN. U. S. 1,551,935, Sept. 1, 1925. In a glass working mach., the combination of two blowpipe receiving devices, means for translating such blowpipe devices with the blowpipes thereon in the same vertical plane, a marverer located in the said plane and acting upon the glass on the blowpipes carried on said devices.



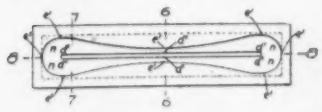
Machine for the production of glass articles. BENJAMIN D. CHAMBERLIN. U. S. 1,551,933, Sept. 1, 1925. In a mach. for the production of glass articles, the combination with a horizontally traveling frame, of a blowpipe carried thereby and movable in respect to the frame in the direction of, and at angles to, the movement thereof, substantially as described.



Method and apparatus for feeding glass. OLBERT C. NOBLE. U. S. 1,552,497, Sept. 8, 1925. The method that comprises causing a stream of molten glass to flow vertically toward a mold having a downwardly converging glass-receiving cavity, intercepting the end of the said stream in a gathering cup having a cavity converging downwardly at an angle greater than the angle of convergence of the said mold cavity, accumulating a shaped gather of glass in the said gathering cup, severing the said stream at an unattenuated

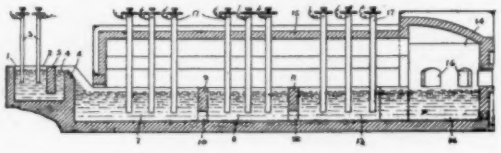


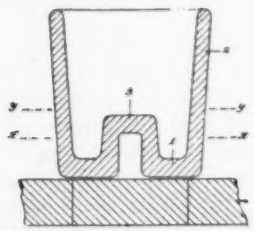
portion thereof above the said cup, and releasing the said gather from the said cup and permitting the said gather to fall vertically into the said mold cavity.



Arrangement for controlling or regulating the thickness of sheet glass obtained by vertical drawing. ERNEST DELACUVELLERIE. U. S. 1,551,980, Sept. 1, 1925. A die piece for sheet glass manuf. consisting of a body having a slot thereon for the escape of glass during drawing, the lower portion of said slot varying in width from the center to the ends thereof.

Glass-refining furnace. ALLAN GRAUEL. U. S. 1,552,555, Sept. 8, 1925. A glass refining fur. having a melting chamber at one end and a work chamber at the other end, a plurality of intermediate chambers between said melting chamber and said work chamber, and htg. electrodes arranged in each of said intermediate chambers.

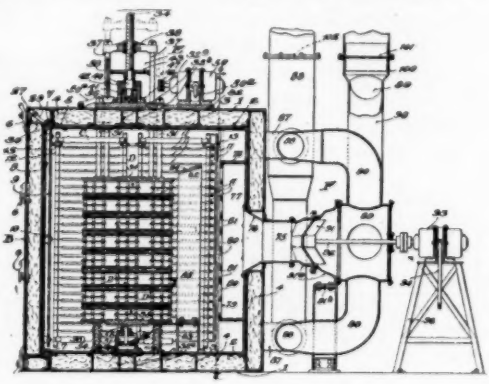




Pot for melting glass. HANS SCHNURPFEIL. U. S. 1,552,884, Sept. 8, 1925. A pot for melting glass, the bottom of said pot comprising a hollow rib, projecting into the interior of the pot and opening to the exterior so that it can be freely traversed by flames and combustion gases.

Method and apparatus for splitting glass cylinders. PAUL R. PIKE. U. S. 1,553,103, Sept. 8, 1925. The method of splitting glass cylinders which includes supporting a cylinder at the bottom portion thereof, burning the cylinder adjacent the bottom portion, rotating the cylinder, splitting the rotated cylinder adjacent the bottom portion thereof, applying a cutter to the cylinder at the burned portion to effect a split at that point, and causing the insertion of a separator between the edge portions formed by the first splitting operation to prevent scratching of the glass by such edge portion when the subsequent split is made, substantially as described.

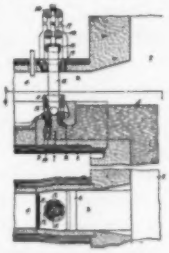
Process of treating glass during annealing. JOHN BENNETT. U. S. 1,553,283, Sept. 8, 1925. The process of treating glass consisting in confining said glass while hot in an air-tight receptacle and exhausting the air and gases from said receptacle.

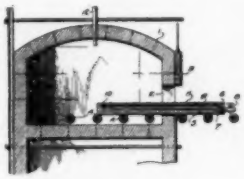


Apparatus for fabricating reënforced glass. WILLIAM C. BULL. U. S. 1,553,667, Sept. 15, 1925. An app. of the class described, comprising an oven, a multiple press device including a stack of horizontally arranged press units accessible through a side wall of the oven, heating means distributed in said oven about the press units, and

means for coursing air currents through and about said press units parallel to the plane thereof.

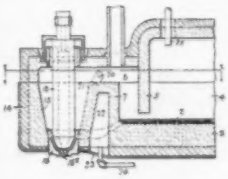
Valve for molten glass. GEORGE E. HOWARD. U. S. 1,553,290, Sept. 8, 1925. A valve for molten glass comprising a horizontal partition member provided with an inlet channel and with a vertical opening communicating with said channel, a tubular stationary valve member having its lower end supported on said partition in line with said opening and having an internal annular valve seat and at least one lateral discharge opening above said valve seat, and an elongated vertically movable valve member having a tapered lower end adapted to rest upon said annular valve seat.



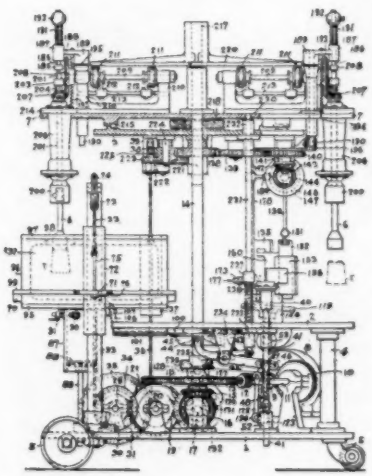


Method of making glass plates. WILLIAM E. HEAL. U. S. 1,553,773, Sept. 15, 1925. The herein described method of making glass plates which consists in placing a layer of glass on the upper surface of a substantially horizontal supporting medium having a lower fusing point than that of the glass, and htg. the glass and supporting medium to a temp. at least as high as the fusing temp. of the glass.

Feeding molten glass. GEORGE E. HOWARD. U. S. 1,553,819, Sept. 15, 1925. In a glass feeding app. the combination of a glass conducting channel comprising a vertical front wall, said channel being formed with a discharge well or passageway extending downwardly, a reciprocating plunger projecting downward into said channel to control the flow of glass therefrom, and a baffle projecting upward from the floor of the channel, said baffle being immediately behind the plunger and extending laterally beyond the side surfaces of the plunger in position to deflect the flowing glass to opposite sides of the plunger.



Machine for fire polishing and finishing glassware. ANDREW J. SANFORD and JOHN B. TOWNSEND. U. S. 1,554,038, Sept. 15, 1925. App. for fire-polishing and finishing glassware comprising a circular series of stations, including a ware-receiving station, a plurality of fire-polishing stations, a finishing station and a ware-removing station, a rotatable carrier disposed above the said stations and carrying a series of vertical punties, means at the said ware-receiving position for automatically attaching the ware to the said punties, a separate htg. chamber at each of the said fire-polishing stations, burnishing and shape-restoring means at the said finishing station, and automatic ware-detaching means at the said ware-removing position.



Heavy Clay Products

Use of slag in industry. K. ELLERSICK. *Feuerungstechnik*, **13** [20], 245(1925).—Describes complete method and equipment used in the manuf. of brick out of blast fur. slag

with lime bond. Attention is called to the fact that indus. is coming to the use of its by-products in this way for its own construction work as an economic measure.

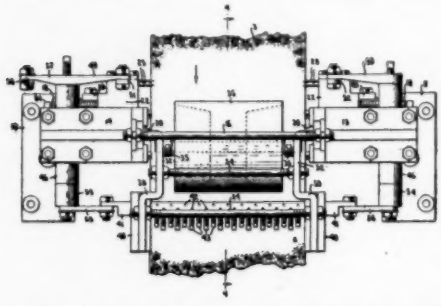
F. A. W.

The rapid production of vitrified clay ware by the combined effects of heat and pressure. A. J. DALE. *Gas Jour.*, **171,** 30(1925).—By using 20 lbs. per sq. in. at 1100°C calcareous earth, Witley marl, cone 16 mixt. and vein quartz became vitrified. This did not occur without press. nor would Stourbridge clay become vitrified under such treatment. S. S. C.

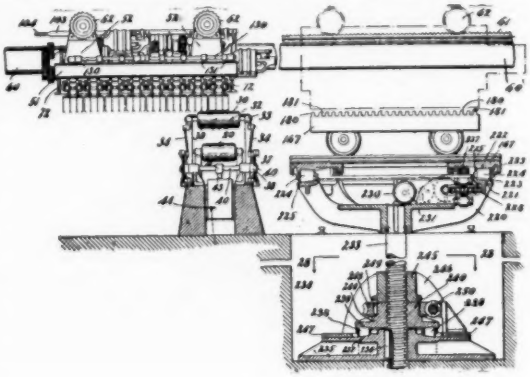
Report on recommended minimum requirements for masonry wall construction. ANON. Special Pub., Bur. Stand.—The proposed requirements cover all types of masonry mats. They define, for the purpose of the report, certain terms not uniformly interpreted in the industry and regulate the height, spacing of lateral support, thickness, working stresses and quality of materials for solid brick walls and those of hollow construction, walls of hollow units, both clay and concrete, stone and plain concrete. Requirements are given for the construction of fire walls and fire division walls and of masonry partitions, both bearing and non-bearing. One article is devoted to masonry wall requirements; another to new types of masonry construction which may be developed; and still another to the precautions which should be observed in lining or increasing the height of existing walls. H. F. S.

PATENTS

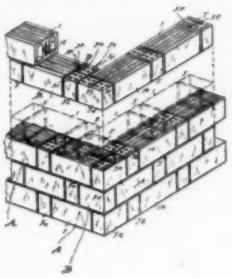
Brickmaking machinery. CHARLES W. HARDWICK. U. S. 1,550,696, Aug. 25, 1925. The combination with a conveying belt adapted to convey a plastic clay article, of a plurality of harrowing points past which said belt moves, means for holding said points from moving along said belt while permitting them to move at right angles thereto, and a gaging device movable with said points and limiting their entrance into the clay bar.



Apparatus for automatically hacking brick. GRAFTON E. LUCE. U. S. 1,551,890, Sept. 1, 1925. App. for handling articles comprising a movable carrier adapted to be supported from an overhead position and having a plurality of independently movable article engaging portions, means to position said carrier in alinement with a support on which the articles to be moved are placed, means for effecting successive relative movement between the article receiving portions of said carrier and the said support, means to move the carrier successively for said successive loading positions and mechanism for effecting a loading action by a relative substantially vertical movement of the article receiving portion and the support.



Hollow-tile flemish-bond wall construction. FREDERICK HEATH. U. S. 1,553,858, Sept. 15, 1925. A wall construction, consisting of hollow blocks arranged in courses and comprising two forms of blocks, one form having three longitudinal voids, and the other form extending transversely of the wall and having vertical voids, its length being equal to the width of the longitudinal blocks and its height equal to the height of that block, and arranged in the wall at intervals without destroying the even continuity of the mortar beds the corners being formed by the vertical void blocks.



Refractories

The relation between under-load refractoriness, ordinary refractoriness, and composition, physical and chemical, of refractory materials. A. J. DALE. *Gas Jour. Supplement*, **171,** 14–23(1925).—Load tests upon 16 commercial bricks and upon 6 exptl. mixts. were made using 50 lbs. per sq. in. and a htg. rate of 50°C per 5 min. The effect of grog was studied in the 6 exptl. bricks and an empirical equation was devised relative to subsidence and time. The types of failure of the commercial brick were discussed, giving curves showing expansion and subsidence. The effect of texture and porosity upon refractoriness and load behavior was investigated. It was found that the ordinary refrac. is not a reliable criterion of the behavior of fire brick under load conditions at high temps., nor can fusion point be taken as an infallible indication of the rigidity of the brick at lower temps. In the tests all brick showed diminution below 1300°C. The failure is preceded by deformation over an extended range of temp. The rate and amount of deformation d under load at 1350°C is related to time t by the equation $d = t^m/a$, where m is a constant characteristic of the mat. and a is the time required for first arbitrary subsidence. With the exptl. grog mixt. m was lower with high grog mixt. than lower grog mixts. The mats. were classed according to these results. S. S. C.

The influence of oxidizing and reducing atmospheres on refractory materials. A. E. VICKERS AND L. S. THEOBALD. *Gas Jour.*, **171,** 27–30(1925).—Fusions were made in an elec. fur. using various atmospheres and additions of Fe_2O_3 were made to cone mixts. Nitrogen was used as the basis of the report for a standard gas. Air acted on the fusion midway between N_2 and O_2 with O_2 giving slightly higher values. SO_2 and CO_2 act slightly as reducing gases lowering the fusion points as Fe_2O_3 increases. H_2 acts strongly as a reducing gas lowering the fusion 250°C in highest Fe_2O_3 content or 2.5% Fe_2O_3 in Thivier's earth. S. S. C.

Notes on testing for refractoriness and after-contraction: A few experiences with refractories in vertical retorts. T. F. RHEAD AND R. E. JEFFERSON. *Gas Jour.*, **171,** 31–41(1925); *Gas World*, **82,** 625–8(1925).—The various tests on refracs. are discussed and the means of detecting failures from various sources. The question of fusion method was taken up and variations in results described. For after-contraction measuring, pieces of cardboard were used to avoid wear of micrometer. Length of piece measured in four places. The taking of samples was gone into and lab. tests and technic described. In vertical retort work the measurement of expansion was described by the using of a water cooled datum mark. Curves of the expansion of the retort are given. The condition of the flues of a dismantled retort was described and photographs were given showing the state of the refractory. The action of producer gas was well demonstrated in this setting. In all retorts near the nozzles in the flue wearing away of the refractory was evident. In some places spalling was bad while others had little or none. Bad fusion was evident in fire brick retorts and slight in siliceous. Practical indications were

obtained on the regulation of the rate of rise of temperature during the initial heating of a setting, the need of accurate limitations of temp. below a prescribed maximum and a method of applying a modified Mellor and Moore load test result to indus. considerations. S. S. C.

An investigation of the effects of load temperature and time on deformation of firebrick material at high temperatures. A. J. DALE. *Gas Jour.*, **171**, 41–6(1925).—The study of the effect of rate, load and temp. in tests upon fire brick is reported. The flow of fire brick mat. under stress at temps. within the subsidence range is qualitatively analogous with the stress-flow relations of "plastic" mats. at ordinary temps. and a yield load range flow exists at a given temp. with the subsidence range. At loads below the yield load range, flow under stress is probably viscosity effect. The higher the temp. the lower is the value of the yield load. Providing a certain temp. is exceeded the deformation-temp. relation is an exponential one, *i..e.*, $D = ce^{bt}$ where c and b are constants for a given loading. Below this temp. the deformation-temp. relation is a linear one, *i. e.*, $-D = kt$. S. S. C.

Some fallacies to be avoided in standardization of load bearing capacity of refractories at high temperatures. T. F. RHEAD AND R. E. JEFFERSON. *Gas Jour.*, **171**, 46–9(1925).—Various load testing methods were reviewed and new means described. The fallacy of heating at 1350°C for 2 hrs. is shown by 2 bricks being heated beyond this at a rate of 50°C per 5 min. The one failing before at 1350° did not fail until 1450°C was reached while the second one started to shrink at 1350°C. The subsidence is compared to that of a viscous mat. The tests were suggested to be made to evaluate the tendency of mats. toward viscous deformation at high temps. under heavy loads and to obtain the plastic deformation under low load at max. working temps. The results of the work showed that a consideration should be made of (1) the temp. at which subsidence becomes apparent, (2) the temp. at which marked acceleration of subsidence occurs, (3) the subsidence range, (4) the effect of load on the temp. extent of subsidence range, (5) the appearance of the piece after testing. S. S. C.

Alumina-silica minerals in firebrick. W. J. REES. *Trans. Ceram. Soc.* (Eng.), **24** [1], 23(1925).—Extractions were made on pieces of five fire bricks of various alumina-silica ratios (49–43 to 67–27) both as received and after reheating to cone 18 and cone 26. HF was used for 12 hrs. at constant temp. The amt. of insol. residue increased with increased temp. and analyzed close to the compn. of mullite. F. G. J.

Some properties of clay-sillimanite mixtures. H. S. HOULDSWORTH. *Trans. Ceram. Soc.* (Eng.), **24** [1], 33(1925).—Test pieces were prepared of mixts. of Farnley fire clay and commercial sillimanite in various propns. These were tested for drying and firing shrinkage, porosity, true and apparent sp. gr., refractoriness, reversible thermal expansion, resist. to slag attack, and resist. to attack by soda-lime glass. Results are summarized as follows: (1) The addition of sillimanite to clay decreases the drying and firing shrinkages, increases the porosity at higher temps. of firing and (when 50% or more is added) increases the refractoriness appreciably. (2) A mixt. of 95% sillimanite, 5% ball clay has a regular coefficient of expansion from 15–1000°C which is not affected appreciably by differences in the firing up to cone 18. The rapid expansion of fire clays from 100–122°C and from 500–600°C is reduced by the addition of sillimanite. The expansion of a typical fire clay from 600–1000°C is less than that of sillimanite for the same range. (3) Sillimanite bonded with 10% of ball clay has a marked resist. to chem. attack by soda-lime glasses and basic slag. Sillimanite-clay mixts. contg. less than 50% sillimanite are not appreciably more resistant to such attack than fire clay alone. F. G. J.

Note on the storage of silica refractories. W. J. REES. *Trans. Ceram. Soc.* (Eng.), **24** [1], 62(1925).—Laboratory tests show loss of strength and increase of spalling

due to exposure. There are definite indications that this is due in part to a slight degradation of the bond as well as to physical effects. F. G. J.

The true specific gravity and after-expansion of lime-bonded silica bricks. W. J. REES. *Trans. Ceram. Soc.* (Eng.), **24** [1], 66(1925).—Forty bricks were studied. Where lime content is between 1% and 3% there is a sufficiently close relation for practical purpose between time, sp. gr. and deg. of quartz conversion. F. G. J.

Testing of fire-clay brick with special reference to their use in coal-fired boiler settings. R. F. GELLER. Bur. Stand., *Tech. Paper* **279**.—Following a conference of Govt. representatives and users and producers of fire clay refracs. held at the Bur. of Stand., a voluminous field survey report was obtained through the coöperation of Stone & Webster and refracs. of 42 brands representative of the product as manufactured in the U. S. were submitted to an extended investg. in the lab. In the lab. the refracs. were subjected to the following tests: (1) An endurance test (in which brick were held at 1450°C for 72 hrs., both with and without load); (2) a reheating test (in which the change in vol. and porosity was detd. after the brick had been held at 1400°C for 5 hours); (3) a quenching test; (4) the standard A. S. T. M. load test, and modifications of this test; and (5) the softening points were detd. by the cone method; and brick of each brand were analyzed chemically and several examd. petrographically. It was found that a close relation existed between data obtained in the endurance, reheating, quenching, and softening point tests, and that these depended to a remarkable extent on the chem. compn. The results indicated that a refrac. which would successfully withstand 15 quenchings from 859°C to running water had a softening point equiv. to at least that of cone 32; that the linear change in the endurance test would not exceed 2% and when transversely loaded the deflection would not exceed 10–32 in.; that the per cent absorption after the reheating test would lie between 6 and 10%; and also that the refrac. should be composed of raw mats. containing not more than 4% flux and 20% uncombined quartz. The results also favor the dry-press process for mfg. brick. It was found that refracs. which appeared of highest quality in the lab. did not always give the highest service, but this was to be expected since no two brands of refracs. were subjected to similar service conditions. The filed survey showed, however, that in practically every instance brick fail primarily through erosion, indicating lack of refractoriness and resistance to the fluxing action of molten coal ash. The one exception is the suspended arch in which the refracs. fail mainly by spalling. In addition, the data from the survey indicate that where the life is relatively long the brick fail by erosion while, with a short life, the failure is due to combined erosion and spalling. H. F. S.

The color-tint test for refractories. ANON. *Chem. Age*, **13** [316], 4(1925).—The specimen after cleaning is boiled in a soln. of equal parts of strong hydrochloric acid and saturated aluminum chloride. After cooling it is thoroughly washed in water and then treated for half an hour with a concd. soln. of methylene blue. After washing the tint effect which gradually fades away is observed. The differential tinting produced varies it is said with the firing temp. of the brick, their different constituents and the impurities present. The quartz transformation phases are also revealed by this method. E. J. T.

Use and manufacture of silica bricks. R. JORDAN. *Chaleur et industrie*, **6**, 135–9 (1925).—A discussion of the qualities required and of the defects which must be avoided with a detailed description of the method of manuf. by which these results are obtained. (*C. A.*)

PATENTS

Refractory and method of making the same. KARL P. MCELROY. U. S. 1,551,201, Aug. 25, 1925. In a basic refractory mat. granular fragments of shrunk, burnt dolomite exteriorly provided with a less refrac. layer of dolomite mat.

Refractory brick. WALTER CROW and JOHN C. SCHAFFER. U. S. 1,553,143, Sept. 8, 1925. A refrac. body comprising a chemically stabilized body-forming refrac. sintered mat. and a humid heat sintered binder for the mat. coacting in the formed body not to detract from mat. refrac. properties and leaving the body superficially sealed and the interior unclinkered.

White Wares

"Pinholes:" causes and remedies. Some due to faulty clay blunging. H. J. PLANT. *Chem. Age*, **12** [301], 14(1925).—Pinholes might be caused in numerous ways such as by the imperfect prepn. of the body mats., imperfect blunging, insufficient aging, a faulty pump, pumping air instead of clay, bad pugging, deleterious press cloths, dust on the molds, perished molds, too much water used by the potter, cost molds being too dry, too wet or too hot, bad firing and faulty glaze mixture. E. J. T.

Revival of porcelain manufacture in Vienna. ANON. *Jour. Roy. Soc. Arts*, **73** [3772], 385(1925).—A new porcelain factory which was officially opened in Vienna recently is meant, says the U. S. Consul at Vienna, to revive the fame of the Imperial Royal Porcelain factory (K. K. Parzellau-fabrik), which closed its doors in 1864 after 146 years of uninterrupted activities. The factory will produce cups, vases, tea and dinner sets striving for quality and artistic finish. E. J. T.

English and American china clays compared. Impressions of a home producer. J. W. HIGMAN. *Chem. Age*, **12** [301], 8–9(1925).—Observations from a visit to china clay mines located in S. Car., Ga., Va. and Pa. English china clays which are dried by evapn. regarded as superior to the American which are pressed and consequently hard. E. J. T.

Experiments with porcelain glazes. A. PFAFF AND W. RATH. *Trans. Ger. Ceram. Soc.*, **6** [2], 63(1925).—Results obtained with porcelain glazes depend on many factors, such as compn. of glaze, compn. of body, length of firing, compn. of fire gases and duration of firing period as well as fineness of raw materials used. The object of these expts. was to det. by empirical methods to what degree the results obtained with different glazes corresponded with what was to be expected from the glaze formula as devised by Seger, and also the effect of diff. raw materials and firing conditions. Compn. of glazes used was:

	Al_2O_3	SiO_2	RO	
Glaze I	0.6	6.0	0.2 K_2O	For all glazes.
Glaze II	1.2	6.0	0.2 MgO	
Glaze III	1.2	12.0	0.6 CaO	
Glaze IV	0.6	12.0		

Crazing was found where SiO_2: Al_2O_3 was greater than 10, the network of cracks becoming finer with increasing SiO_2. A second batch of the same glazes fired in a similar kiln under supposed identical conditions showed somewhat diff. results, noticeably in the crazing limit. The use of diff. raw materials did not change the general relationship but resulted in a shifting of the characteristics. Further tests were made with the addition of coloring oxides. F. A. W.

Finishing of fired refractories. C. GRUPP. *Tonind. Zeit.*, **49**, 351(1925).—Regarding the milling of brick. W. S

Electrical melting of quartz according to the vacuum-compression method. HUGO HELBERGER. *Umschau*, **29**, 373–6(1925).—To melt quartz clear and free of bubbles the author used crucibles of silicium carbide. The melting chamber was vacuated and the solidification took place under press. of compressed gases. The best material for optically perfect glass is quartz crystal from Brazil and from St. Gotthard. W. S.

Some recent developments in the utilization of casting scrap in the casting slip. E. A. SLAGLE AND ANDREW FOLTZ. *The Ceramist*, **5** [3], 140–3(1924).—Casting scrap can be used in casting slip only if p_H value of slip is accurately controlled. The optimum p_H value depends on the clays used. Values used in actual practice are given. A. E. R. W.

Factory tests for feldspar. JOHN M. KREGER. *The Ceramist*, **5** [5], 260–7(1925).—K. describes expts. proving that a simple fusion test is worth very little to a potter. K. suggests actual introduction of the feldspar to be tested into the glaze batch and testing under actual factory conditions. K. stresses the value of a visit to the source of supply. A. E. R. W.

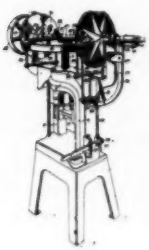
Some recent developments in the utilization of casting scrap in casting slip. C. C. TREISCHEL. *The Ceramist*, **5** [5], 272–3(1925).—The casting scrap is blunged, mixed with water, and its hydrogen ion concn. brought to the same value as the regular combination of body ingredients. T. cautions against using acetic acid to neutralize a body contg. whiting as it causes "pinholing," or the use of the process in a raw slip without first washing out the soda salts as it causes "soda blisters." A. E. R. W.

Porcelain for electrical purposes. ANON. *Quarry & Surveyors' & Contractors' Jour.*, **30**, 185(1925).—In a recent issue of *Technische Blätter*, there is an article on the quality of porcelain used for elec. insulators. O. P. R. O.

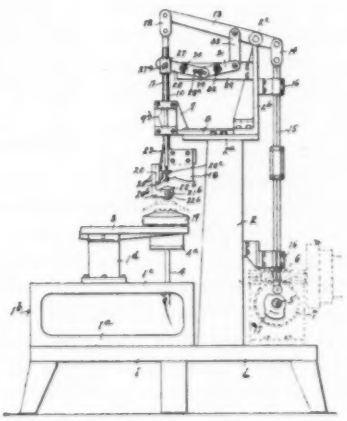
Spark plug. M. WATAYA. *Report Osaka Ind. Research Lab.* (Japan), **5** [8], 1–30(1924).—German spark plug porcelain (Robert Bosch make) was chemically and microscopically analyzed. W. then prepd. various porcelain bodies using 5 different sources, and compared them with others. The ratio in all mixts. was $MgO:Al_2O_3:SiO_2 = 12.33:0.95:19.58$. The ingredients used were (*a*) talc, (*b*) SiO_2, (*c*) Korean kaolin, (*d*) Japanese clay, and (*e*) a Manchurian rock (the last contg. 16% loss on ignition, 44 SiO_2, 0.57 Al_2O_3, 0.91 Fe_2O_3, 0.25 C, 47.82 MgO). Conclusions: The main constituent of the porcelain of Bosch spark plug must be talc. If the porcelain is made of talc, with limestone as a fluxing agent, the product is not good from every point of view. The porcelain contg. the Manchurian rock as a body possesses the highest insulating power at a high temp. but its resistance to quick temp. change is greatly lowered. The porcelain contg. 80 parts talc. and 0–15 clay is the best and kaolin is much better than plastic clay. The product thus prepd. is superior to the Bosch in insulating power, resistance to extreme changes of temp. as well as to higher voltages. Full data are given. (*C. A.*)

PATENTS

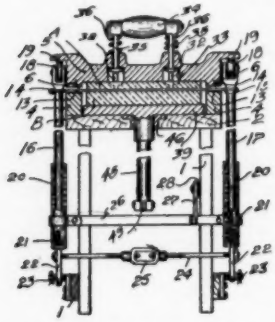
Pottery-forming machine. MARTIN BURGER. U. S. 1,551,728, Sept. 1, 1925. In a pottery-forming mach., a rotatable mold carrying a charge of plastic mat., and a mat. distributing roller engaged and rotated by said rotating charge of mat. whereby the latter is prevented from being thrown off by centrifugal force and is given the desired form.



Tile press. WILLIAM HENRY IVENS. U. S. 1,553,243, Sept. 8, 1925. In a tile press, a screw having a friction wheel on its upper end, a slidable power shaft above the wheel, friction disks on the shaft, a

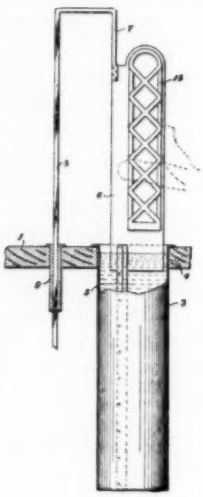


brake mounted on the shaft to engage said friction wheel, a pivoted lever, a rod connecting the brake with one end of the lever, a pivoted shift arm having one end extending under the free end of the lever, manually operated means for operating the shift arm, a sleeve carried by the power shaft, and a spring-pressed rod in the sleeve and to which the other end of the shift arm is pivoted.

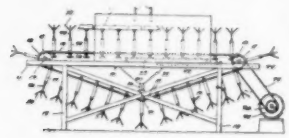


Tile-making machinery. ARTHUR B. FOSSEEN. U. S. 1,552,478, Sept. 8, 1925. In a tile-making mach., the combination with a press having lateral guide slots in its walls, of a cutter extending transversely through the press and adapted to reciprocate in said slots, an extensible supporting arm for each end of said cutter and alined pivots for said arms, and means for swinging said arms to reciprocate the cutter in its slots. In a duplex-tile mach. the combination with means for cutting a rectangular chunk of plastic mat. into wedge-shape tiles, of means for punching the respective tiles to form nail holes.

Method and apparatus for applying slip. RAYMOND J. GREENE. U. S. 1,552,556, Sept. 8, 1925. The improved method of applying slip to adjoining surfaces of a two-part clay structure, which consists in placing the adjoining surfaces against opposite faces of a "slip" coated blade and sliding the blade from between said surfaces. An app. of the character described, including a tank, a guide rod, a series of lazy tongs connected to the guide rod, a treadle connected to the lazy tongs, a blade connected to the guide rod and extending into the tank, and means for normally holding the treadle in raised position.



Glazing machine. JOHN D. BOWMAN and THEODOR J. ROTH. U. S. 1,553,133, Sept. 8, 1925. A device of the character described comprising a supporting frame, an endless conveyor movable therealong and equipped with drive means, a plurality of supports carried by the conveyor and adapted to carry articles to be glazed, shields carried by the frame between which the articles pass, means entering between the shields for spraying glazing liquid onto the articles, a hood through which the articles pass subsequent to spraying, and heating means within said hood whereby to effect drying of the articles.



Equipment and Apparatus

Determination of grit in clays. G. M. DARBY. *Chem. Met. Eng.*, **32**, 688–90 (1925).—The author made a comparative test of 5 methods. 1. Elutriation (Nobel app.). 2. Flotation (Sutermeister method). 3. Flotation (A. D. Little method). 4. Centrifuging. 5. Wet screening. For grit coarser than 325-mesh, wet screening using satd. 100-, 200-, 325-mesh screens is the best method. Elutriation gave the most accurate results but was too slow for routine testing. The Sutermeister flotation method was promising, being both rapid and accurate. The A. D. Little method did not give consistent results, and the centrifugal method was impractical because of the necessity for varying the speed for different clays. A chart is given for converting particle diam. readings to mesh figures. M. E. M.

Optical pyrometers. W. E. FORSYTHE. *J. Opt. Soc. Amer.*, **10**, 19–37(1925).—A summary of theory and methods of use of optical pyrometers. D. E. S.

Comparing relative cost of base metal and rare metal thermocouples from actual plant experience. ANON. *Brick & Clay Rec.*, **66** [8], 602–3(1925).—A paving brick manufacturer in decreasing the firing time from 12 days to 6 days found that in "forcing" the kilns in this way, the life of the base metal thermocouple was decreased from 6 fires to less than one. Rare metal couples were installed and the replacements during 4 years of service have been due almost entirely to accidents outside of the kiln. The couples are annealed annually at a cost of $2.00 each, which constitutes the chief cost of maintenance. In addition, rare metal couples indicate the temp. correctly. P. D. H.

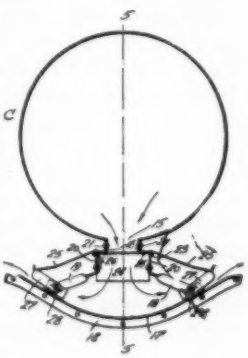
Optical instruments. F. TWYMAN. *J. Soc. Chem. Ind.*, **44**, 797–8(1925).—The British optical industry, though smaller than the German, is better situated than before the war. Apochromatic objectives are now provided superior to any foreign make. Research on filter-passing micro-organisms demanded an accuracy of focusing and a rigidity not provided by any existing stand, and such a stand, has now been evolved. Improvements in illuminating systems include the combined illuminator used in recent investigations on the cancer virus. British binoculars have a bigger field of view than any other, and camera lenses are also superior. The 41″ aperture disk of the largest telescope in the world has been successfully made. The Sci. Instrument Research Assoc. has discovered the origin of differences in transparency of glass. H. H. S.

Tyler electric silica still. J. C. OLSEN, W. LINDENTHAL AND I. SHERMAN. *Trans. Am. Inst. Chem. Eng.*, **16** [1], 101–10(1924).—Detailed description of a still designed and constructed by S. L. Tyler, of the Thermal Syndicate, and made entirely of SiO_2, except for the heating element, which is enclosed in a SiO_2 tube. Tests are given showing utilization of the elec. energy with an efficiency of up to 92%. It may be used to produce distd. H_2SO_4 and other acids of very high purity and of practically any concn. H_2SO_4 may be concd. to over 97%. (*C. A.*)

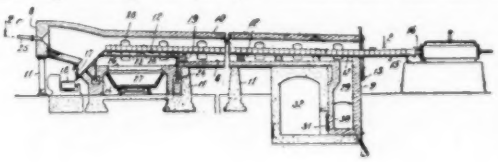
A handy, simple photometer for the measurement of low transparencies. ENOCH KARRER AND A. PORITSKY. *Z. tech. Physik*, **6**, 266–8(1925).—2 cuts. (*C. A.*)

PATENTS

Air conditioning and distributing apparatus. ALFRED E. STACEY, JR. U. S. 1,550,714, Aug. 25, 1925. The combination of an air distributing duct which is open along one side thereof for the discharge of air from the duct, means for delivering air to the duct, a deflector extending lengthwise of the duct opposite said discharge opening and arranged to leave openings between its side edges and the duct for the escape of the air laterally between the deflector and the duct, and means for varying the width of said openings between the duct and deflector to regulate the discharge of the air.

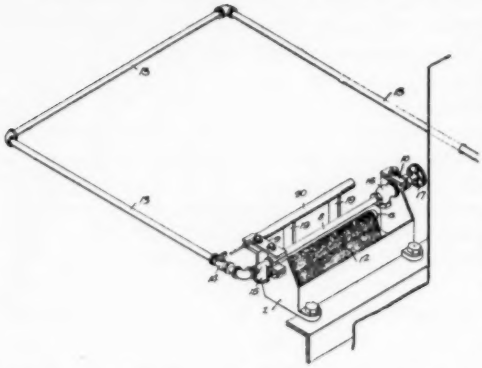


Continuous-heating furnace. WILLIAM HENRY FITCH. U. S. 1,551,945, Sept. 1, 1925. A continuous htg. fur. comprising a htg. chamber, a combustion chamber adapted for the burning of pulverized fuel, a track in the htg. chamber for guiding mat. to be heated, a supporting frame for the track traversing the region of high temp. within the heating chamber to permit the

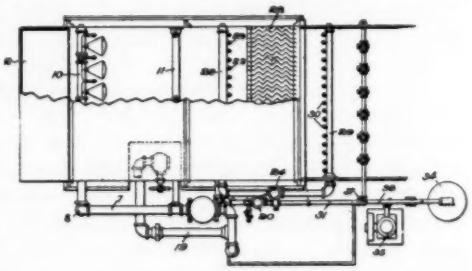


free circulation of hot gases around the mat. to be heated, said track and frame being composed of hollow members to permit the flow therethrough of a cooling fluid, a chamber below the region of high temp. of the heating chamber for collecting and trapping refuse formed during the combustion of the fuel, said chamber having an easily removable bottom portion, and means permitting the removal of refuse deposited in the heating chamber.

Wet-bulb thermometer. THOMAS H. RHOADS. U. S. 1,553,962, Sept. 15, 1925. The combination of a box arranged to contain water; a centrally located outlet for the box; a wet bulb thermometer located above the box; a wick extending over the thermometer and into the box on each side of the outlet; a water pipe having an opening through which water is supplied to the wick; and a screen surrounding the outlet of the box and extending upward in the space between the two ends of the wick.



Apparatus for supersaturating air. JAMES JARVIS PREBLE. U. S. 1,554,185, Sept. 15, 1925. An app. for cleaning, humidifying and supersaturating air and conveying the same to a point of use, comprising in combination an elongated casing having at one end an inlet for the untreated air, a transversely extending series of nozzles within said casing near the air inlet and comprising means for driving, washing and humidifying the air, a second transverse series of nozzles beyond said first series, for scrubbing and further humidifying the air, means for supplying water to both said sets of nozzles, means for collecting, straining and returning to said nozzles the excess water, transversely extending eliminator plates in said casing beyond said second series of nozzles, for removing readily precipitated particles of free moisture from the washed and humidified air, flushing nozzles at opposite sides of said eliminator plates for periodically cleaning the latter, said flushing nozzles being controllable independently of the other nozzles, a plurality of supersaturating nozzles in said casing beyond said eliminator plates in the direction of air flow, and means for supplying water and air under pressure to the same whereby water in extremely comminuted condition is introduced into said air to supersaturate the same, and enclosing means communicating with the casing for conducting the air in such condition to a point of use.

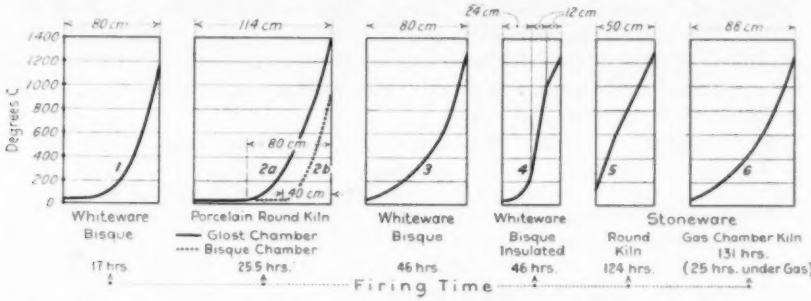


Kilns, Furnaces, Fuels and Combustion

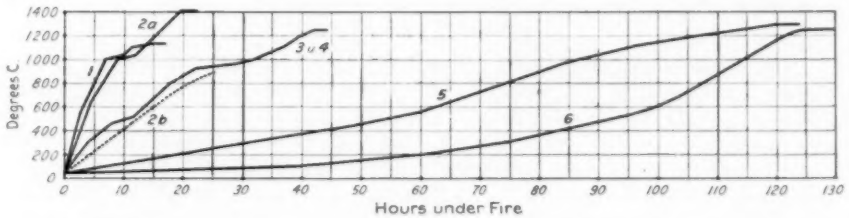
Suction air preheater. E. KLOSE. *Feuerungstechnik*, **13** [15], 183(1925).—Describes a combination of forced draft and preheater app. using products of combustion. Draft, capacity and press. can be regulated to conform with the quantity of fuel used.

F. A. W.

Heat flow in the walls of ceramic kilns. H. WILLMER. *Trans. Ger. Ceram. Soc.*, **6** [2], 49(1925).—Pyrometer readings were taken at different depths in the wall of two round whiteware, one porcelain, one round vitrified tile and one gas-fired chamber kiln. Four nickel-nickel-chromium thermocouples were inserted in holes running into the kiln wall from the door at a height about 6 ft. from the kiln floor, experience having showed that this elevation approximates average conditions between floor and



crown. These holes were 20″ deep, slightly staggered and about 6″ apart. Temperature readings were also taken of the outside kiln wall and of the fire gases between the kiln wall and first row of saggers. The accompanying curves show results obtained. Calculations based on results obtained showed kiln walls, crown and floor as absorbing 12.8–18.9% of the total heat produced. The gas chamber kiln showed loss through absorption through crown, 2 ends and bottom of 25%. From these tests a formula



was developed governing the penetration of heat into kiln walls: $S = A\sqrt{Z}$ where S = depth of penetration in cm., Z = length of firing period and A a coeff. obtained from the equation $A = S/\sqrt{Z}$. Further formulas are given analyzing the relationship between kiln load and length of burn and heat absorption by walls, etc., per cu. ft. of kiln vol. Tests with insulated kilns showed a reduction of 43% in heat absorbed. Calculations showed a possible saving of 7% fuel on a completely insulated kiln of the type tested. F. A. W.

Oil firing as applied to ceramics. L. A. MEKLER. *The Ceramist*, **5** [4], 204–16 (1925).—M. stresses the importance of correct firing, compares the properties of oil and coal fires, and points out the changes that should be made in kiln construction and operation when oil is substituted for coal as fuel. Charts illustrating the principles of heat transfer and the performance of a muffle kiln are given. A. E. R. W.

A rapid fire tunnel kiln for smaller ceramic wares. TAINE G. MCDOUGAL. *The Ceramist*, **5** [5], 268–71(1925).—A description of 3 small continuous tunnel kilns of an effective and interesting type. A. E. R. W.

PATENTS

Firing of ceramic masses, especially porcelain, in tunnel kilns with direct gas firing. ALLGEMEINE ELECTRIZITAETS GESELLSCHAFT. German Pat. 411,881.—Nozzles

are provided in the air pressure line which soak hot air from the cooling zone and heat so the compressed air is used at the burners. In order to obtain ware free of culls it is necessary that the chem. compn. of the flame is different in the reducing and preheating zone. The invention allows to adjust the compn. of the flame so as to be reducing in the reducing zone, neutral or little reducing in the high fire zone and oxidizing in the preheating zone. W. S.

Firing of ceramic ware in tunnel kilns. PORCELAIN FACTORY PH. ROSENTHAL AND CO. German Pat. 412,401. The gas which is accumulating in the upper sections of the tunnel is burned by introducing air through thermocouple holes into the zone where the pores of the ware begin to close up. In doing that one avoids blistering the ware near the crown of the kiln. W. S.

Geology

Antimony in Bolivia. ANON. *Jour. Soc. Chem. Ind.*, **44**, 820(1925).—Bolivia is capable of producing large amts. of Sb, and could more than make good the present shortage. The ores contain a considerable amt. of gold and it is often possible to carry out the production of the two metals simultaneously. H. H. S.

Cornish china stone. Its value to the ceramic industry. ANON. *Chem. Age*, **12** [305], 14(1925).—Cornish china stone is a type of partially decomposed granite found only in the neighborhood of St. Austell, England. It is employed both in the body and in the glaze of wares. When added to an earthenware or porcelain paste it assists by its fusibility in the vitrification. In glazing mixt. it is one of the less fusible ingredients and acts as a stiffener. Cornish stone vitrifies at about 1200°C. E. J. T.

Chemistry and Physics

The action of heat on kaolinite and on kaolinitic clays. W. VERNADSKY. *Trans. Ceram. Soc.* (Eng.), **24** [1], 13(1925).—V. offers a different explanation from Mellor and Scott (*Trans. Ceram. Soc.*, 1924). He thinks that all observed transformations correspond to one and the same process. One mol. of water is replaceable by bases and is lost at 450–460°C with absorption of heat. The other called zeolitic water, disappears on heating proportionately with the temp. and is in solid soln. in the crystalline space lattices. During this dehydration kaolinite is changed to anhydrous leverrierite, $Al_2Si_2O_7$ which is stable up to 1000°C. Many reasons are advanced to support the presence of this compd. Above 1000°C leverrierite decomposes to cristobalite and mullite or keramite. V. claims to have suggested the presence of some such compd. in 1891. Structural formulas of these compds. are proposed. F. G. J.

X-ray investigations of clays and some other ceramic substances. ASSAR HADDING. *Trans. Ceram. Soc.* (Eng.), **24** [1], 27(1925).—X-radiographic anal. is of two different kinds, either "molecule" anal. or "atom" anal. "Atom" anal. corresponds to chemical anal. but can never quite substitute it. "Molecule" analysis is like optical investigation but is effective on micro- and crypto-crystalline subs. In mol. anal. the prepn. is irradiated with X-rays of known wave-length. The crystalline particles then produce secondary X-rays which give characteristic diagrams. These diagrams are interpreted by comparing with those of typical substances. Complicated diagrams may be simple to interpret. F. G. J.

The influence of exposure on the chemical and physical properties of certain fireclays. W. HUGILL AND W. J. REES. *Trans. Ceram. Soc.* (Eng.), **24** [1], 42(1925).—Three samples were studied. They were broken into pieces 2″ in diameter and spread evenly over the bottom of wooden boxes covered with fine muslin and exposed for a year. Meteorological conditions are recorded. Comparative chem. analyses of samples

before and after exposure show a loss of sol. salts and an increase of refractoriness. The rate of settling was not much altered. Bricks were made, fired, and tested and microstructures photographed. Exposure improved siliceous clays more than an aluminous one. F. G. J.

A rapid method for the determination of true (or powder) specific gravity. W. HUGILL AND W. J. REES. *Trans. Ceram. Soc.* (Eng.), **24** [1], 70(1925).—The app. consists of a flask of 250-cc. capacity with graduation for this amt. Above the mark is a bulb, then a long neck graduated in specific gravities from 2.00 to 2.70. Liquid is added to the lower mark, then 100 gms. of powder is poured in and the gravity read direct. Organic liquids may be used to reduce soly., surface tension and viscosity. F. G. J.

Notes on rational analyses of clays and kaolins. ANON. *Keramos*, **4** [7], 353 (1925). F. G. J.

A test of relative decolorizing efficiencies of clays. J. B. HILL, L. W. NICHOLS AND H. C. COWLES. *Ind. Eng. Chem.*, **17** [8], 818(1925).—A test was needed for the proper control of kiln revivifying spent fullers' earth or clay from the filtration of heavy petroleum oils. Such a test was devised and is described. F. G. J.

The sixth international conference of pure and applied chemistry. J. C. DRUMMOND. *Jour. Soc. Chem. Ind.*, **44,** 811–2(1925).—The conference met this year from June 22 to 25 in Bucharest, Roumania. Discussions were held on the nitrogen problem, autoxidation and catalytic phenomena, and the relation between chem. constitution and physiological activity. Excursions included one to Medias, Transylvania. where large factories for enameled iron, sheet glass and bottles are run by natural methane of compn. 99% CH_4 and calorif. value 8500 cals. per cu. m. An invitation by the Americans to hold the Seventh Conference in Washington next year was accepted. H. H. S.

Effect of light on kaolin suspensions. C. G. T. MORISON. *Proc. Roy. Soc.*, **108A,** 280–4(1925); *Jour. Soc. Chem. Ind.*, **44B,** 617(1925).—During expts. on the application of the Goldberg wedge to an optical method of detg. the size distribution of particles in soils, it was observed that the passage of a beam of light caused soil and kaolin suspensions to become stratified, the layers running parallel to the surface of the suspensions. The distance between successive strata varies with the wave-length of the light. On cutting off the light, the stratification slowly disappears. H. H. S.

Calculation of products of combustion. W. GUMZ. *Feuerungstechnik*, **13** [16], 195 (1925).—In flue gas analysis it is customary to consider all C as changed to CO_2 and CO. This does not take into acct. C left in ash and carried away in solid form as soot or smoke. Using formula devised by A. B. Helbig, tests on a certain Ruhr coal show a direct loss of C in solid form as high as 9%. F. A. W.

General

Alumina from china clay. What experiments reveal. ANON. *Chem. Age*, **13** [318], 11(1925).—The method proposes to prepare alkaline aluminate by fusing clay lime and scrap iron with a reducing agent in the elec. fur., thereby reducing the silica and forming calcium aluminate and ferrosilicon. The calcium aluminate being lighter will flow to the top substantially free from foreign oxides. It could then be tapped off, cooled and later crushed and leached with sodium carbonate soln. to form by double decompn. sodium aluminate and calcium carbonate. The former is sol. and yields readily aluminum by hydroxide. The ferrosilicon would be recovered as such and sold at a profit. The reactions are thought to be as follows:

1. $Al_2O_3.2SiO_2.2H_2O + Fe + 4C + CaO = FeSi_2 + 4CO + CaO.Al_2O_3 + 2H_2O$
2. $CaO.Al_2O_3 + Na_2CO_3 = CaCO_3 + Na_2O.Al_2O_3$

The cost of the production of alumina by the method would be more than $300.00 per ton. There was no proof that calcium aluminate was formed, because, with so much carbide present, it was just as likely that the sodium aluminate obtained was formed by the decompn. of aluminum carbide and its soln. in the sodium carbonate.

E. J. T.

New method for determination of the expansion in high temperature. HANS HIRSCH AND MAX PULFRICH. *Tonind. Zeit.*, **49**, 452–3(1925).—Description of the process which is carried on with a precision cathetometer designed by the authors.

W. S.

Tables Annuelles de Constants et Données Numériques. 4 [1] (1913, 1914, 1915, 1916).—1. Elasticity, (*a*) Young's modulus (Fe, Al, Cu, glass, quartz, etc.), (*b*) Elastic limit (Fe electrolytic, glass), (*c*) Quartz threads. 2. Viscosity, (*a*) Blast furnace slags, (*b*) Viscosity of glasses. 3. Coefficients of Expansion, (*a*) Linear expansion—quartz, silicates, glasses, porcelain, enamels. 4. Specific Heats, (*a*) Brick, (*b*) Latent heat for molten quartz and of various metals. 5. Thermal Conductivity, (*a*) Glass. 6. Melting Points, (*a*) Inorganic compounds (list of systems studied), (*b*) Inorganic compounds-organic compounds (list of systems studied), (*c*) Ternary mixtures—elements and inorganic compounds (list of systems studied). 7. Intra-Red Spectral Region, (*a*) Coefficient of transmission of red glass (Jena). 8. Coefficients of Absorption, (*a*) Transparency of glasses and color filters. 9. Refraction and Dispersion, (*a*) Optical glasses. **Tables Annuelles de Constantes et Données Numériques. 4** [2] (1913, 1914, 1915, 1916).—10. Electric Conductivity, (*a*) Various substances (Al, paraffin, S, resin, wax, glass, etc.), (*b*) Spar, quartz, glass, rock crystal, (*c*) Quartz, (*d*) Electric dilation of solid insulators under the influence of an electrostatic field. 11. Magnetic Susceptibility, (*a*) Various substances (quartz, hydrates, etc.). 12. Magnetic Rotation, (*a*) Quartz, (*b*) Graphite. 13. Diffusion, (*a*) In solids—Ag ions in soda glass. 14. Calorimetry and Thermo-Chemistry, (*a*) Heat of adsorption, of transition, (*b*) Total heat of formation. 15. Crystallography and Mineralogy, (*a*) Melting points of minerals, (*b*) Transition temperatures. 16. Engineering, (*a*) Mechanical constants—building materials: (1) Influence of size of sand on the strength of mortar, (2) Strength of various cements, (3) Influence of various addition in the water of mortar, (4) Trass mortar, (5) Various materials: Magnesia and alumina, strength of plaster, glass, porcelain, road materials, brick walls, coke, (*b*) Electrical constants: (1) Technical properties of porcelains for insulation, (*c*) Refractory materials: (1) Melting points of fire brick, (2) Shrinkage of "Veritas" firing rings, (3) Thermal conductivity of refractory materials, (4) Softening points and analysis of refractory materials, (5) Melting points of slags, (6) Shrinkage at high temperatures of zirconium dioxid crucibles, (7) Formation temps. of constituents of Port. cement during the burning of the clinker composed only of Ca_2O, Al_2O_3, SiO_2, (*d*) Refractory materials: (1) Specific heat, (2) Thermal condy., (*e*) Melting points: (1) Various materials—silicates, phosphates, sulphides, (2) Refractory brick, (3) Slags, (*f*) Refractive indices: (1) Colloidal silica and natural glasses, (2) Liquid crystals and mixtures of liquid crystals, (3) Essential oils (variation with temperature), (4) Oils for steam turbines, (5) Fluids of the body. **Tables Annuelles de Constantes et Données Numériques. 5** [1] (1917, 1918, 1919, 1920, 1921, 1922).—1. Elasticity and Compressibility, (*a*) Quartz, glasses. 2. Coefficients of Expansion, (*a*) Quartz, silica, glasses, (*b*) Coefficient of linear dilation of glasses for laboratory materials. 3. Viscosity of Quartz. 4. Surface Tension, (*a*) Glass. 5. Specific Heats, (*a*) Pyrex glass, silica, and silicates, various minerals. 6. Thermal Conductivity, (*a*) Quartz, glass, etc., (*b*) Brick. 7. Melting Points, (*a*) Inorganic compounds (list of systems studied). 8. Coefficients of Absorption or of Extinction, (*a*) Influence of temperature on the transmission of light through colored glasses,

(*b*) Transparency of colored glasses used in the Hess-Ives photometer. 9. Indices of Refraction Dispersion, (*a*) Optic glasses, (*b*) Primary etalons in quartz, (*c*) Glass for use in the laboratory, (*d*) Crystals and glasses of disilicate of Ba included in Ba-crowns, (*e*) Annealing, birefringence and tension of glasses, (*f*) Double refraction in melted silica, (*g*) Refraction indices of the striae in optical glasses, (*h*) Refraction, dispersion and composition of optical glasses, (*i*) Binary glasses. 10. Electricity, (*a*) Glasses, (*b*) Silica, insulators, (*c*) Variation of conductivity with high frequency and with the dielectric constant: (1) Glass.

The properties of clays. A. V. BLEININGER. *2nd Colloid Symposium Monograph*, **1925,** pp. 80–98.—The properties of clays are considered under the following heads: aggregate structure, mineral composition and micro-structure, fineness of grain, chem. compn., clay suspensions, plastic state, dry state, effect of heat, fired state, testing. (*C. A.*)

Plasticity in colloid control. E. C. BINGHAM. *2nd Colloid Symposium Monograph*, **1925,** pp. 106–13.—B. stresses the importance of plasticity along the lines brought out in his book "Fluidity and Plasticity." By using long capillary tubes and properly evaluating seepage and slippage, the formula $V = \mu(F-f)r$ will probably be found to hold over a wide range of shearing stresses. Here μ is the mobility (the reciprocal of the consistency ζ), F the shearing stress in dynes per sq. cm., and r the distance between the two shearing planes. "Notwithstanding that clear and indubitable evidence has now been found that in suspensions the flow is a linear function of the shearing stress, and the yield value obtained is quite independent of the dimensions of the instrument, nevertheless in colloids of the emulsoid type, evidence is found for exactly the opposite conclusions. The flow of emulsoids through a long capillary is not a linear function of the shearing stress, and the yield value cannot be obtained by simply extrapolating the flow-stress curve, for with capillaries of different radii non-concordant values for the yield value would be obtained." This evidence (to be published later) was obtained by Hood, Arnold and B. To explain the sharp distinction between the two types of colloids, it must be recalled that internal friction is due to two causes: (1) *diffusional viscosity*, resulting from interdiffusion of molecules having different amts. of transitional energy, (2) *collisional viscosity*, caused by actual spacial interference as the layers are sheared over each other. In liquids far removed from the crit. temp. (1) is of small importance, and the viscosity due to (2) follows Batschinski's law that fluidity is proportional to free vol. Chem. combination consequent on heat or pressure may qualify the law, which applies to suspensions as well. In suspensions a third cause of internal friction is the rotation of particles in the shearing process, energy being continually absorbed from the external stress in breaking down transient "structures." Hence flocculation increases yield value. Work is being continued on the structure effects in emulsoids. In many cases "m. p." is without scientific value. (*C. A.*)

Some applications of thermels in the measuring technic of large-scale chemical industry. P. GMELIN. *Ann. Physik*, **76,** 198–224(1925).—(1) *O as impurity is measured* in H and in N almost instantaneously as the gas streams by, by using a catalyst and furnace (350° or so) in a side stream. The heat produced is measured by a thermel of from 8 to 24 couples, and a sensitive voltmeter. *Constant speed* of the gas, a very important factor, is secured by a series of constrictions, alternating with outlet tubes dipping in liquid, constituting overflow pressure regulators. Failure of the stream, or excessive impurity, rings an alarm. In one case the app. indicated 0.1 per mille of O within a minute, and rang the alarm at 0.5 per mille. (2) Variations in the *composition of producer gas* are continuously measured by a calorimeter which consists of a flame radiating to a thermopile. Marquardt capillaries increase and make more uniform the radiating power of the flame. The lag is about 20″. (*C. A.*)

Lead borates. E. C. BROWN AND J. R. PARTINGTON. *Jour. Soc. Chem. Ind.*, **44**, 325–6T(1925).—Methods used by earlier workers to prep. Pb borates by fusion and pptn. were tried out, but no positive evidence was obtained for the existence of a simple borate of Pb. The (1) occlusion of $Pb(NO_3)_2$ by the ppt., and (2) the effect of washing, are important factors. Such borates of Pb as have been described are really basic substances whose compn. depends upon the method of prepn. (*C. A.*)

Chemical constitution of brick clay. A. DEMOLON. *Compt. rend.*, **180**, 1518–20 (1925).—Quartz and combined SiO_2, Al_2O_3, free and combined Fe_2O_3, MgO, K_2O, combined H_2O, and p_H are tabulated for the clay and the 5 fractions into which it was sepd. by levigation. The results indicate an isomorphous mixt. of alumino- and ferri-silicates. Identification of glauconite in the sand fractions indicates if as the source of the ferri-silicates, of the K_2O other than that from mica, and of the free Fe_2O_3. The deposit contains no appreciable amt. of S compds., though the tertiary deposits from which it originates contain numerous pyritic elements. There is 0.4–0.7% total P_2O_5 and no free Al_2O_3. (*C. A.*)

An artificial magnesium silicate. A. DAMIENS. *Compt. rend.*, **180**, 1843–5(1925).—When a soln. of Na silicate is pptd. with $MgSO_4$, no definite compd. is obtained, and part of the Mg Na silicate stays in colloidal soln. In fractionating the deposit, it yields silicates from $2SiO_2(MgNa_2)O$ to $SiO_2(MgNa_2)O$. (*C. A.*)

The labradorization of the feldspars. O. B. BØGGILD. *Det. Kgl. Danske Videnskabernes Selskab, Math-fys. Medd.*, **6** [3], 3–79(1924).—Labradorization is the reflection of light from submicroscopic planes, which usually have but one orientation for a given specimen. The planes never have a position capable of expression by simple indices. Aventurization is entirely different (cf. Andersen, *C. A.* **9**, 3192). B. examd. 53 specimens of feldspars showing this phenomenon. Only certain varieties have labradorization: *orthoclase* contg. Or_6Ab_1 to Or_1Ab_2; *albite-oligoclase* with 8–14% *An*; and *labradorite* with 38–49% *Ab*. In orthoclase the labradorization is caused by intergrown lamellae of albite, at 72–75° to (001) in the zone of the orthodomes. In the plagioclases there are 4 different orientations of the planes of labradorization, but the effect is generally visible through (010). In the plagioclases the cause is unknown. (*C. A.*)

Some artificial mineral compounds. P. J. HOLMQUIST. *Geol. För. Förh.*, **47**, 142–4(1925).—Quartz brick in a Martin furnace undergo changes in chem. compn. at high temp. Noticeable amts. of Fe are taken up. About 2% of the Ca content is lost. Under the slag are found small, dull yellow, rhombodecahedral crystals of *melanite*. Tridymite, cristobalite, magnetite and an undetd. slag silicate rich in Fe were also found. A deposit of *magnetite* in a Platen-Munter cooler (using NH_3 and H_2O at 10 atms. and 140°) was investigated. In the 6-mm. Fe tube, where the NH_3 was most rapidly evolved from the liquid, octahedral crystals of magnetite were found. Where the NH_3 was evolved more slowly the crystals were smaller. A soot-like powder of magnetite was found throughout the whole interior. The magnetite is carried as such in the NH_3 soln., from which it separates by direct crystn. Fe ore briquets were subjected to elec. arc flame. The easily flowing melt on cooling crystd. as magnetite, coated by oxidation in air with a thin layer of hematite which at high temp. formed a twinned laminated variety. Two forms of crystd. Fe_2O_3 exist—a high temp. (β-) and a low temp. (α-) form. (*C. A.*)

Economic utilization of waste heat for generating steam. F. WINTERMEYER. *Feuerungstechnik*, **13** [14], 169(1925).—Discusses the tremendous economic saving possible and construction of suitable types of boilers. F. A. W.

Coke from lignite. HUDLER. *Feuerungstechnik*, **13** [17], 208(1925).—Describes method of extracting tar and coking lignite. Increased gas content gives only 1% higher heat value but reduction of moisture content increases efficiency. F. A. W.

Thermotechnical application of Schoop process. E. BELANI. *Feuerungstechnik*, **13** [19], 232(1925).—This process involves the spraying of objects with metal dust by means of a special gun which feeds the metal in wire form through an oxy-hydrogen flame and a comp. air nozzle at $2^1/_2$ atmos. Thickness of coating up to $^3/_8$". Prepn. of surface with sand blast recommended. Expts. with grate bars heated to high temp. and coated with aluminum showed remarkable results, increasing their life 600% over similar bars uncoated. Further advantages are the lessened adherence of clinkers and consequent blocking of the openings and low cost of application. Treatment applicable to any metal parts subject to high temp., *i. e.*, boiler linings and tubes, retorts, stills, etc. F. A. W.

Individual or group drive. ROBERT W. DRAKE. *Brick & Clay Rec.*, **66** [8], 594–7 (1925).—This article has been reprinted from *Industry Illustrated*, issue of Sept., 1924. In general, there is a field where each type of drive is supreme and it is folly to attempt to apply the other. There is a large middle ground where either may be used and where each case must be decided upon its merits. This article offers a number of suggestions to aid in such a decision. P. D. H.

Is the Diesel engine good equipment? R. H. BACON. *Brick & Clay Rec.*, **66** [8], 598–600(1925).—This is an educational article describing the operation of the Diesel engine and pointing out why it is dependable, economical and desirable power. P. D. H.

Industrial chimneys. ANON. *Contract Rec. and Eng. Rev.*, **39**, 542(1925).—A discussion of the construction of all types of indus. chimneys. Highest concrete stack on the continent is in British Columbia. Radial brick chimneys are built with special blocks formed to suit the circular and radial lines of each section of the chimney and molded with vertical perforations. There are several advantages in these: perforations permit a more thorough firing of the blocks in the kiln, and produce a more homogeneous block than could be obtained were they solid, and their strength and density are thus materially increased. On account of their radial form tight joints are obtained, this, with air space due to perforations, gives max. conservation of heat inside chimney. On account of the high refrac. powers of the blocks, long protective linings may be eliminated. O. P. R. O.

Silicate of soda in road construction. ANON. *Roads and Road Construction*, **3**, 229(1925).—Results obtained by the use of silicate of soda on roads in Switzerland are given by M. Guelle in the Feb. 21 issue of *Gen. Civil*, 1925. Guelle estimates that the use of silicate of soda saves at least 30% or more, under some conditions. (1) The silicated roads, with regular use, have for vehicles a very smooth surface. (2) As compared with ordinary roads with an average traffic, a saving may be effected which according to the district may vary from 30% to 80%. (3) Thaws have no influence on them. O. P. R. O.

Blue asbestos. ANON. *Jour. Soc. Chem. Ind.*, **44**, 796(1925).—Ordinary white asbestos (chrysotile) found in many parts of the world, is essentially a hydrated Mg silicate. Blue asbestos, or crocidolite, which occurs only in S. Africa, contains a considerable amt. of iron, and is a ferrous magnesium silicate with less moisture content, and of a deep lavender blue in color. It possesses many advantages over the white variety, the fibers being longer, $^3/_4$ to 2", with considerably higher tensile strength, while it has a lower sp. gr. and is very much more resistant to high temps. It is thus not only good for covering steam boilers and pipes, but, being entirely unaffected by acids and alkalis, finds extensive application in chem. industry for packing rings, filter cloth, etc., and in marine work for segments, ropes and mattresses. Tests by the Nat. Phys. Lab. show that as a non-conductor of heat it is 20% better than white asbestos. It saved 94% of the loss from a bare steam-pipe at 300 lb. press., and it appears to last indefinitely, installations having been in opern. for 15 years at 425°C. H. H. S.

Fuel economy. HENRY WILLIAM SELDON. *The Ceramist*, **5** [2], 105–17(1924).—S. stresses the importance of fuel economy to plant executives, emphasizing the practical side. S. relates steel and glass plant experiences to show the importance of coöperation and instruction of operators in attaining fuel economy. S. gives a summary of good operating instructions under the following headings: (1) competent operators are invaluable, (2) requirements must be standardized, (3) coöperation is necessary, (4) supervision must be constant, (5) standards of practice should be established and checked. The use but not utter dependence on pyrometers, draft gages and other efficiency instruments is urged. Factors influencing the efficiency of the actual combustion such as (1) air supply, (2) size and aeration of flame, (3) chem. compn. of gas burnt, (4) difference in temp. and intimacy of contact between gas and bath, (5) velocity of gases, (6) speed of firing are discussed. The characteristics of the different fuels and types of gas producers available and their relation to fuel economy is taken up in detail. The advantages of mechanical producers and automatic combustion regulating devices are given. A. E. R. W.

Ancient earthenware. ANON. *The Ceramist*, **5** [4], 222–34(1925).—Pictures and descriptions of pit houses and earthenware found in the prehistoric habitations of Chaco Canyon, New Mexico. A. E. R. W.

The state trade school for the glass industry in Zweisel. BRUNO MAUDER. *Keramos*, **4** [7], 349(1925).—A long article descriptive of the courses taught. One of a series of such articles. F. G. J.

Progress of ceramics and its importance for the chemical industry. F. SINGER. *Keramos*, **4** [7], 359(1925).—The chem. industry depends on ceramics for (1) the development of the mechanical resist. of ceramic wares; (2) the development of chem. resistance, especially resist. to bases; (3) development of refracs.; (4) development of resist. to temp. change; (5) development of the density or porosity of mats; (6) construction of special mats. for special purposes. F. G. J.

Utilization of waste heat from tamps. BJARNE SCHIELDROP. *The Glass Worker*, **44** [47], 15(1925).—Waste heat has been used for boilers at open hearth steel furs. for 15 years and recovers up to 30%. This has been little used on glass tanks. The necessary conditions are considered. F. G. J.

BOOK REVIEW

Pueblo Pottery Making. A study at the village of San Ildefonso. CARL E. GUTHE. Introduction by A. V. KIDDER. Published for the Department of Archaeology, Phillips Academy, Andover, Mass., by the Yale University Press, 1925. 8 x 11". 88 pages, 35 plates, 11 figures. Price $4.00.

Dr. Kidder in the introduction very clearly compares conditions in Southwestern America with those in Egypt and shows how native pottery supplies the key for the chronological sequence of changes of culture. A study of the ancient fragments is well supplemented by investigating modern methods. The modern Indians are little different from their remote ancestors of before the conquest. Lately they had degenerated in pottery making until the Museum of New Mexico and the School of American Research stimulated a revival of the industry. Certain of the Indian women have made real progress both technically and artistically. Maria Martinez, whose picture forms the frontispiece of the book, seems to have been the most successful. The incomes made by these women have built up the community.

A very intimate story is detailed of the entire process of Pueblo pottery making. The reader is taken to the sources of raw materials, introduced to the tools, and carried painstakingly through every stage of the process. Frequent footnotes compare similar

details given by Stevenson in an account of Zuni pottery making. Tables are given of the minutes and seconds required for each series of operations. The occasional suggestion of other household activities of the potter relieves the monotony for both reader and worker. While scientific details are absent, no mechanical step is slighted in the description. All ware is made by the single fire process. Slipping, polishing and decorating are done on the sun-dried pieces. Designs are absolutely free-hand, without pattern.

The firing is perhaps the most casual process of all. Pots are set on any kind of a grate and built over with slabs of dried dung. Cedar wood kindlings are burnt below. In twenty to thirty minutes the oven is broken up and the pots pulled out. Another lot is set at once. Four firings are often made in one morning, the last being a reducing fire to give black ware. Throughout the book frequent photographs are reproduced showing the details of each step in the process of manufacture.

The book is an excellent story of domestic pottery and should be of interest to all who love form and design and who long to potter around with clay.

F. G. JACKSON

Meetings of the Society

This SOCIETY functions in part by meetings at which papers are read and topics discussed. One such meeting was held in New York, October 1, to discuss whether product and product requirements should be stressed more in school curricula. Eight papers were read and a lively discussion had. At one time there were 120 persons in the hall and several other members reported as present.

In the evening we had a delightful banquet at the Hotel Roosevelt with Dr. Herty, Senator Wadsworth and Editor Abbot as speakers. Edwin M. Rupp of Continuous Tunnel Kiln Corporation of America was the local representative making arrangements.

Now for the big Annual Meeting to be held in Atlanta, February 8–13. From what the Division officers report we are to have a great meeting, one that will profit all who attend.

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BULLETIN

of the

American Ceramic Society

A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical, Scientific and Art Questions and Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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EDITORIAL

ALLOCATION OF BUREAU WORK ON CERAMICS

Field Laboratories and Plant Proving Should Be Continued

Both of the federal bureaus, Standards and Mines, have laboratories and research personnel devoted exclusively to ceramics. Both of these Bureaus are engaged in fundamental science and in empirical or applied science investigations; both are doing coöperative work with associations, corporations and individuals; and both Bureaus are increasing in services rendered and in need for larger support. It is well that the economy and effectiveness of this arrangement be studied.

Since both of these Bureaus are now in the Department of Commerce, Secretary Hoover has appointed a Committee to consider all phases of allocation of ceramic work in the two Bureaus. This Committee is holding hearings, and in November it will have a special session at which delegates from the several ceramic organizations are to be heard. The Committee is composed of industrial leaders in lines other than ceramics, hence decisions made will be impartial.

It is natural and not at all detrimental that each of these two Bureaus should not observe rigidly the limits set for each. A given amount of rivalry has been excellent. Competition is as vital to healthy development in research as it is in all other human affairs. The present arrange-

ment of having two Bureaus engaged in ceramic research each under separate direction is both practical and healthy but, theoretically, and perhaps, practically, it would be well to have all the ceramic work in the one Bureau if this can be done without stifling the ambitions of the bureau personnel which are now prodded by rivalry into doing their utmost.

The two Bureaus are now and always have coöperated in a friendly manner. They have exchanged information and given freely to each other on request. The rivalry between them has been similar to that between two friendly manufacturers who exchange manufacturing information but compete for territory and sales; both Bureaus have been on their toes producing results. The rivalry has been healthy.

What little overlapping there has been in work undertaken by each Bureau has not been detrimental and fortunately the ceramic industries have not suffered in results obtained because of encroachments by each Bureau on the field defined for each by the organic acts. The Bureau of Standards has been the aggressor in this respect but it has cared so well for the tasks undertaken but belonging to the Bureau of Mines that no one has thought of protesting. Indeed, "though out of order," their efficiency has justified the encroachment and the Bureau of Mines has ample scope not encroached upon. Both of the Bureaus have acquitted themselves in ceramics very admirably.

When it comes to transferring all of the ceramic work to one or the other Bureau, as Secretary Hoover has proposed, the ceramic industries have a just reason for protesting because neither Bureau is qualified to do the character of work to which the other one has been devoting the majority of its attention.

The Bureau of Standards is admirably qualified and situated to make investigations on standards, specifications of materials and products, and on simplification of product. They are better qualified to determine the fundamental or scientific facts regarding ceramic materials and products. Qualities and standardization and abstract science work in ceramics are so broad, untouched and important fields of endeavor that it would be well that every support be given by the ceramic industries to the Bureau of Standards in this work.

In glass, vitreous enamels and pottery Standards has large opportunities of rendering valuable service. Past performances in these fields warrant giving Standards a larger and better trained personnel. What they have accomplished has shown the value that would accrue from more intensive scientific work in these fields. If every energy, every thought and every cent that could be made available were devoted to work in these lines the Bureau of Standards would place America in the lead in these fields. To lessen their concentration on these investigations

by placement in Standards the ceramic work now being done by the Bureau of Mines would be defeating the very purpose for which the Ceramic Division of the Bureau of Standards is operated.

The Bureau of Standards, as stated in the last Annual Report of its Director, has organized its personnel for and has paid attention more to the fundamentals required by the ceramic industries. To these, as the Director states, the effort of the Bureau of Standards should be directed. To reverse this policy of the Bureau of Standards or to confuse it by enlargement so as to cover the ceramic work now being done by the Bureau of Mines would not only greatly lessen the effectiveness of Standards but lose the benefits now being derived by the ceramic industries from the Bureau of Mines.

The Ceramic Division of the Bureau of Mines has devoted its attention to mining, preparation, treatment and utilization of ceramic materials. It has studied the means of economically employing ceramic minerals. The beneficiation and industrial use of clays of Georgia and Ohio, of talc, cyanite and dolomite have been studied and carried through and proven in manufacturing.

Study of the economic use of coal and of oil in kilns was only started but the fundamental facts disclosed and the industrial proof made justifies continuance of these fuel studies.

The novel and distinctive work done by the Ceramic Division of the Bureau of Mines has been the proving on plant scale production and under plant conditions the determinations made in the laboratory. The Bureau of Standards has not and would not, without amendment of its policy, undertake plant proving of its investigations.

It has been questioned if this plant proving should not more properly be done by the industries. We believe not.

In the first place, the investigators, fundamental and applied, need the opportunity of bringing their work through to industrial applications, thus making evident to them the discrepancies in their findings, preventing malconceptions and showing the character of fundamental data most needed.

In the second place this plant proving checks the laboratory findings. No laboratory work, no matter how closely it might simulate plant conditions, can be trusted to develop all of the factors which must be controlled in economic plant production.

For instance, for years scientists and plant technologists have sought ways of making refractories from dolomite. Brick and slags standing excellently the laboratory tests and even proving well in trial use, have from time to time been produced. The results of several researches involving fundamental studies of the reactions, the compounds formed, the variations in product made by different heat treatments, the effect

and efficacy of various binders, etc., have repeatedly been considered as finally showing how refractories could be made from dolomite. It was not until the Ceramic Division of the Bureau of Mines made plant scale studies concurrently with their fundamental researches that any degree of success has been attained. No industrial concern independently has solved the problems, and the history of the work on dolomite in the laboratories and in the plants makes plain, we believe, that neither a federal bureau nor an industrial concern independently would have found the several factors and combinations of factors which affected the utilization of dolomite as a refractory. It has required men trained to do fundamental science research observing not only product qualities as affected by variation in plant practice but also product qualities in reference to conditions in use.

We believe firmly that if the government discontinues plant proving of its investigations the Bureau investigators will be less qualified to render service by their fundamental researches and that the industries would not and could not make plant application of the results of the fundamental researches made by the Bureaus.

Then, too, we believe in the federal bureau having stations located in the industrial centers. We believe in a great central laboratory for the fundamental researches leading to standards and specifications but not for application of science to the beneficiation and economic use of minerals and of ceramic products. We believe strongly in field stations and in the Bureau men proving their work under plant conditions.

We agree with Secretary Hoover in the possibilities of larger returns from concentrating all the ceramic work in one Bureau but we would urge strongly against discontinuance of field stations and employment of laboratory cars. Especially do we believe that the work of bureaus would be of much less value to the industries if the bureau men should discontinue plant proving of laboratory findings. We believe in economy and efficiency of the laboratory men carrying through to plant production basis rather than having the bureau men limited to laboratory investigations and depending upon technical men in the industries for proving and making application of the bureau results.

For altogether too many years have the bureaus been content with small scale empirical investigations, and for too long a while have they divorced the fundamental and the applied. We plead for plant proving by men capable of checking or finding the fundamental causes for behaviors of materials and products under plant conditions, and for the doing of this in field laboratories where the maximum of collaboration with the industrial technologist can readily be secured. We are not in favor of the government doing all of the ceramic investigation in one great central laboratory.

PAPERS AND DISCUSSIONS

THE MANUFACTURE OF LEADS FOR THE MECHANICAL PENCIL

By Robert Back

The fashioning of materials into marking leads is one of the oldest ceramic industries, yet practically all there is in the literature are brief references, and the formulas suggested are quite impractical. The literature contains little not found in encyclopedias. Recently some trade journals in this country and foreign countries have had narrative descriptions of processes for making the lead sticks and the wooden casings.

The mechanical pencil has revolutionized methods and formulas for making leads. The severe specifications of size and strength of lead for mechanical pencils make efficient production of them far more difficult than of lead for the ordinary, wood-encased pencil. The various hardnesses of lead for the ordinary wooden pencil results simply from variations in proportions of the materials and in the diameters employed. The diameter of the lead in mechanical pencils is of first importance in developing a practical formula.

The industry is purely ceramic, regardless of the kind of leads. Ceramic materials and many organic materials are used. A thorough understanding of the fundamental principles of ceramic materials and material compounding is necessary for successful lead manufacturing. Control has to be had of plasticity and binding power of the materials, and drying behavior, shrinkage and firing of the mixtures as well as of grinding, purifying, mixing, screening, filter-pressing and pugging.

Materials Used in Black Leads

The materials used in the manufacture of black leads are (1) a blend of plastic binding clays having definite working properties and firing behavior for the various degrees of hardness, (2) graphites, both flake and amorphous, blended according to the quality of leads desired.

The proportion of flaked graphite which can be used is limited. Even 300-mesh flake graphite reduces the binding power of the fine-grain plastic clays relative to the binding power of the same used with amorphous graphite. Especially is this an important consideration in the smallest diameter leads, those having a diameter of 0.0460 inches. Obviously, the larger the diameter of lead the higher can be the content of flake graphite. It is desirable to use as much flake graphite as possible for it imparts smoothness and ease of slip.

The clays and graphites used for black lead must be freed from all gritty material.

Colored Leads

For colored leads similar clays are used but their firing behavior is not important as colored leads are not hardened by firing. Gums, mineral waxes, vegetable tallows

and synthetic organic compositions are used to harden colored leads. Quite naturally, black graphites are not used in colored leads. The smoothness or ease of slip in colored leads is obtained from the finest ground talcs, micas and synthetic organic materials.

Mineral pigments and aniline dyes are used as coloring in the leads. Purity in case of some of the materials is of greater importance in the colored leads than freedom from grit is in black leads, because impurities interfere with the working and forming of the lead. The shrinkage and final strength and perfection are affected by certain impurities.

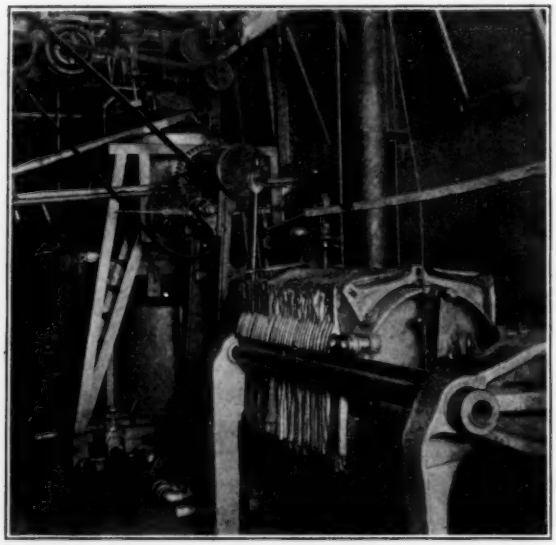

FIG. 1.

The manufacture of hardened colored leads for mechanical pencils is by far more difficult than the manufacture of equivalent fired black leads. Those colored leads which approximate the writing qualities of the fired black leads are the most difficult to manufacture to exacting size limitations, strength specifications, etc.

Manufacturing Processes

Leads of crayon composition and the larger diameter leads of high wax and grease composition are manufactured by a simple extrusion or by casting in molds.

Preparation of the Clays

The clays are aged in storage to develop maximum plasticity and bonding power. They are made into slip by grinding in porcelain-lined pebble mills with deflocculating reagents. They are then pumped to a battery of thirty settling tanks. Satisfactory separation of the gritty material results after four to six days' standing.

Batch Mixing

The grit-free deflocculated clay is syphoned to pebble mills where the graphite additions are made and the batch ground. The time for grinding is exceedingly important, and varies with the physical condition and the percentage content of the flake graphite in the batch.

On completion of the grinding, additional water is added to facilitate pumping and screening through 300-mesh phosphor bronze shaker screens. The tailings are returned to a tank below the pebble mill.

Filter Pressing and Pugging

Figure 1 shows an upper tank which serves as a batch storage. In the double blunger tank below it flocculating reagents are added to the batch. The batch is then thoroughly beaten to a uniform mixture.

The lead mixture for best writing quality presents a most difficult problem in filter pressing. It is plastic and compact. To press water from it is very difficult. As the pressure builds up in the press the impulse of the pump has to be reduced to a minimum, otherwise it would invariably break the cakes and cause the press to leak under the finishing pressures of 250 to 300 lbs. per square inch. To filter press lead mixtures successfully an automatic pressure regulator was designed. This regulator gives sufficient resistance against the pulsations of the pump to give satisfactory even flow even with pumps having excess capacities and reduced strokes. In the line to the press there is an extra large expansion chamber to further reduce pulsations.

FIG. 2.

The filter cakes are put through a vertical type pug mill. The material is extruded in the shape of plugs about 2 inches in diameter. Three or four trips through the pug mill give the desired uniformity in moisture distribution. The plugs are then stored in stoneware crocks under tight cover.[1]

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[1] Acid and alkali resisting paints and other metal protective coats fail to preserve the iron settling tanks, blunger tanks, pug mill, etc., from corrosion. It was found that an application of an alcoholic solution of copal seed gum to perfectly clean metallic surface gives a satisfactory and lasting coat. Asphalt coated wooden tanks would serve better.

Conditioning and Forming

The equipment employed for reducing the moisture content of the 2-inch plugs to that required for satisfactory press extrusion has been designed to obtain uniform moisture distribution. Wahl Eversharp leads are manufactured within diameter limits of variation of only .001 inch. The diameters of the leads would not come within this lim t if the moisture variation from time to time should cause the pressure gage on the hydraulic press to show a variation of $^1/_4$ ton on a ram of 20-square inch cross-section. In the production of leads dependence must be placed on the equipment and processes for assurance of being within dimensional limits, for piece inspection is not practical where the production per month is some 250,000 gross sticks of leads.

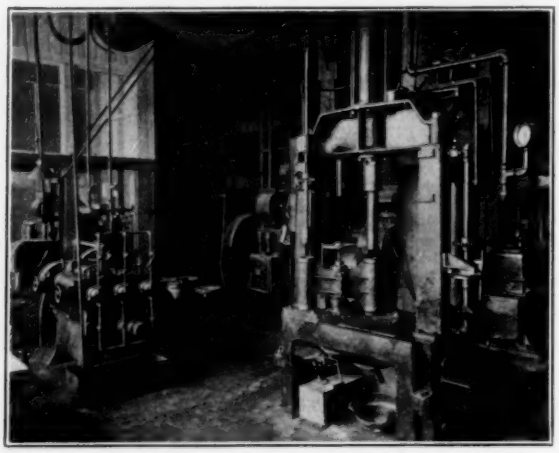


FIG. 3.

Figure 2[1] is a view down the aisle where the lead batches are dried and where the plastic lead coils are formed through diamond dies in hydraulic presses.

In the foreground are stoneware crocks in which plastic lead plugs are awaiting transfer to one of the four humidity drying cabinets just opposite the man in the aisle. The humidity cabinets are separately controlled with thermostats. The humidity driers for the heavy lead plugs are designed to have no circulation of air, whereas those for the formed leads have air circulation. Drying of the plugs is slower where there is so little air circulation but case hardening and excessive drying of the ragged parts of the plugs are thus avoided. The humid air fed into these cabinets leaves the cabinets only through the minute cracks at the doors, etc.

The man in the foreground is unloading a tray of plugs taken from the drying cabinet. They will be put through a small machine similar to a meat chopper. The material is reduced to pellets about $^1/_8$ inch x $^1/_2$ inch.

[1] The illustrations are from the lead plant of the Wahl Co., Chicago, which plant is equipped to manufacture 250,000 gross sticks per month of standard leads in black and colors.

A load of 250 to 300 pounds of pellets is placed into the revolving and tilting drier screen seen in the right foreground of Fig. 2. A fan shaped duct conducts humid air to this screen. A good circulation of air of low drying efficiency through the tumbling pellets causes them to dry very uniformly. Dust particles, which granulate off the ragged ends of the pellets, pass through the screen into a bin below. This avoids excessively dried small particles which would cause hard spots, spots of excessive diameter and points of weakness in the finished lead. The tilting arrangement permits the screen to empty itself.

The man standing at the first hydraulic press is tamping small pellets into one of the press cylinders.

The girl is testing the shrinkage by rapidly drying straightened lengths on an electric hot plate. A record of this is made and goes along with each lot of 25 gross of lead until all work on the lot is completed and it is ready for packing. This rapid drying does not give the true shrinkage. It is indicative of what the production shrinkage will be. This testing likewise affords a check on the wear or any change in size or shape of the diamond die piece.

The Presses

In Fig. 3 is a close-up of one of the lead presses, showing the control equipment. To the left is the tamping rod; at the center is the plunger which forces the lead through the die plate, holding, in the case of black lead, one diamond die. Below is a pan receiving the coil of lead and just above it a whirler device to direct the lead strand into a perfect coil. To the right, just above the base of the press, is a control lever, and just above it a worm gear attachment with which the finest adjustment of pressure and speed of coil forming is effected. On most of the presses the control is obtained with needle valves. The fine adjustment device shown here, however, is the better of the two controls.

FIG. 4.

Equipment and Method for Indelible Lead

To the rear in the center of Fig. 3 is a steam jacketed, phosphor bronze lined dough mixer, in which the indelible lead mixtures are worked up to a tough consistency. The indelible lead mixture is then transferred to the special three roll mill, shown in the left fore-

ground, to complete the drying to the point required for introduction of the material into the lead forming press. For colored and indelible leads the three roll machine, therefore, replaces the filter press.

The various colored lead mixtures also are conditioned and rendered uniform on rolls. These colored mixtures are prepared in small pebble and stone mills similar to those used in the paint industry, some of which will be seen in Fig. 4. The stone mill mixtures require preliminary drying before going to an agitating machine, known as a pony mixer, from which the semi-fluid mass goes to the large three roll machine.

In the foreground of Fig. 4 two operators are shown coiling indelible lead from a pan onto a rotating drum.

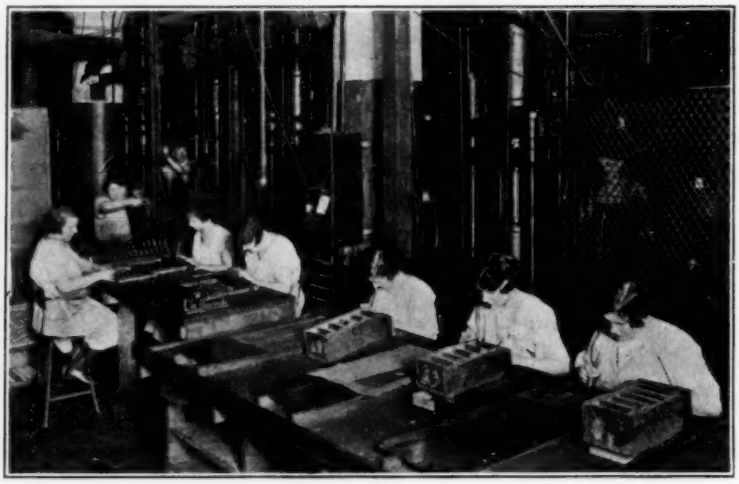


FIG. 5.

The second girl from the left in Fig. 5 is cutting the dried black leads at one end of the four special cutting machines employed for this work. Whereas indelible and colored leads are sawed, the black, unfired leads are cut by means of roller knives under spring tension and perfectly guided in grooved slots. The automatic machinery used for loading the finished leads, in order to operate, requires that the leads do not vary more than $^1/_{64}$ inch in length. The leads are taken from the humidity cabinets before they become bone-dry. This avoids excessive breakage and jagged ends that might result if they are too dry.

The three girls at the bench in the right foreground are rejecting short, broken and any other imperfect leads. The cut leads are placed in containers. A box load of five of these containers constitutes a crucible load for the furnace.

Firing

After the leads have been transferred to clay-graphite crucibles boxes, and the covers sealed, they go to the furnace room, one corner of which is shown in Fig. 6. Each crucible box holds approximately 250 gross sticks of leads and eight of these boxes constitute a furnace load. The fired leads of one furnace load has a retail value of $3600, priced at 15c per dozen sticks of leads in the Red Top Eversharp lead boxes. An average of three firings per day are made, five days a week, throughout the year.

A battery of two furnaces is used, in the first one of which the leads are brought up from a temperature of approximately 200°F through a clay dehydration temperature of about 1200°F.

The eight crucibles are then transferred from this furnace to a second one where the firing is continued on up to temperatures from 1700° to 2100°F in accordance with the degree of lead being made. A shift from one furnace to the other is made to gain the advantage of saving furnace cooling time for the successive firings. This procedure also proves to be easier on the furnace linings and hearths.

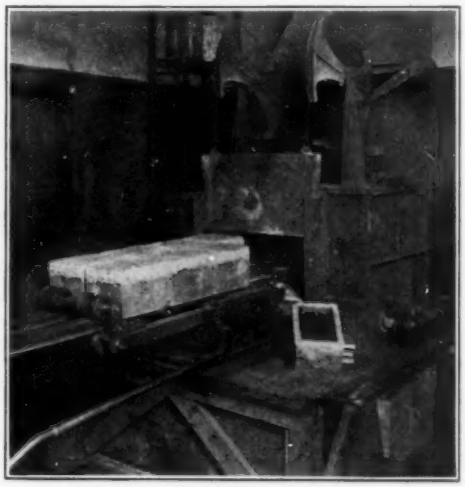


FIG. 6.

The furnaces were specially built. The hearths are carborundum specially designed with resting blocks on which the crucibles are placed. The feeding fork is operated on a turntable and mounted on a truck to facilitate the transfer of the furnace loads, as well as the removal of the hot crucibles from the furnace room to cooling chambers in the next room adjoining.

The outside surfaces of the crucible boxes are glazed, thereby increasing the life of them. The sealing material is a blend of suitable refractory clay and other ingredients to produce just sufficient porosity to permit the escape of the gas without the danger of oxidation of the graphite.

Graphite Ash Effect Firing Schedule

Whereas pencil leads are composed of just two general classes of materials, clays and graphites, yet the blends of clays and the blends of graphites employed make standardizing of the firing process difficult due to the firing behavior of the ash material that is ever present in even the best of graphites.

Appreciable reduction in the percentages of ash in the graphite is pos-

sible by the well-known process of Walter E. Trent for purifying coal, etc., but it is perhaps impractical to expect more than about 50% elimination of the ash. Graphites for which the ash exhibits objectionable firing results had better be replaced by other graphite more suitable.

Knowledge of the initial temperature of vitrification and the temperature range of vitrification before overfiring is reached for this graphite ash is most important, particularly where the lead diameter is small. When vitrification of ash must be contended with firing temperatures employed generally are above that at which the ash vitrifies and overfires.

Leads of larger diameter which permit of higher percentages of clays can be fired to lower heats. For small diameter lead the lower temperature firing may result in ample strength but too harsh a quality, or satisfactory quality and insufficient strength. A guiding knowledge of firing behavior of graphite ashes is therefore important for blending graphites to obtain a uniform product.

FIG. 7.

The total ratio of the graphites to the clays for the various degrees of leads is dependent upon getting a satisfactory blend of the graphites. Materials which will make a most satisfactory lead of .076 inch and larger diameters will not necessarily do so for an .0465 inch diameter lead. A premature strength at a certain heat treatment results partially from the initial sintering of the clay but primarily to the earlier vitrification of the graphite ash. This early vitrification of graphite ash produces a harshness in lead with low strength that would be standard for the softer leads. To control within .001 inch variation in diameter requires a knowledge of variation in firing treatment of the graphite ash.

Testing and Inspection

In Fig. 7 is shown a section of the department where lead diameter measurements are made and cross breakage strength of the fired leads is tested. The fired leads are then soaked in wax mixtures. After solidification of the wax the cross breaking test is again made and a test made for writing quality. The writing quality test consists of writing a few

words, always using the same quality of paper. Diameter testing is made with Brown and Sharpe micrometers. Should rejection be necessary it would be found that either a crucible box has become defective or the thermocouple protection tube needs replacement or some of the control instruments are not operating perfectly. Control of the manufacturing processes rightly deserve the burden for errors. Control must be positive throughout the process if leads are to be profitably made to exact or close specifications.

Waxing and Polishing

The man in Fig. 7 is at the waxing cabinet where fifty gross units of the fired leads are soaked for a given time in a suitable wax mixture according with the degree of lead. After sufficient drip the leads are placed in the heated, rotating tumbler shown in the left foreground. Hardwood sawdust of definite fineness is tumbled with the leads to reabsorb the wax from the surfaces of the lead to prevent the leads from sticking together.

After sifting the leads from the sawdust they are placed into a second shaker where the leads are polished. A permanent polish could be made only by aging sufficiently for the maximum exudation of wax on the surface before subjecting the leads to a polishing treatment. The grayish color due to excess wax or lack of polishing has no important bearing on the quality or strength of the lead. Softer grades of leads will show this wax accumulation more than the harder grades.

The waxing treatment of colored leads is very much more difficult without changing strength and diameter of the colored leads. Waxing of these leads is primarily to coat them, making them less absorbent to moisture. Practically all makes of colored and indelible leads will soften and swell materially under certain conditions of temperature and humidity, such as in a man's pocket during the warmer months of the year.

THE WAHL CO.
CHICAGO, ILL.

NOTE ON AN UNUSUAL CASE OF WARPING OF FLAT WARE IN THE GLOST KILN

BY THOMAS A. SHEGOG

This case occurred purely by accident. It became necessary to use a different glaze for decoration considerations from the ordinary type of glaze in regular use.

So I tried out a glaze which was given several years ago by a very well known English ceramist in which, instead of feldspar, we used Cornwall stone and instead of boric acid we used borax.

The composition of the glaze was this:

Frit		Mill	
Borax	23.5	Frit	40.25
Whiting	18.5	Flint	10.50
Flint	30.5	Cornwall Stone	28.75
Soda Ash	12.75	White Lead	21.00
China Clay	14.75		
	100.00		100.50

That is the composition of the frit, which I only write down for the purpose of showing that in addition to borax and no boric acid, we introduced soda in the form of soda ash. I do not know why, but you will see the effect that produces in the molecular formula.

The molecular formula for that glaze is:

$$\left.\begin{matrix} 0.262\ PbO \\ 0.340\ Na_2O \\ 0.051\ K_2O \\ 0.346\ CaO \end{matrix}\right\} 0.280\ Al_2O_3 \left\{\begin{matrix} 2.822\ SiO_2 \\ 0.230\ B_2O_3 \end{matrix}\right.$$

The alumina is almost exactly one-tenth of the silica and the oxygen ratio is 3.44/1.

Perhaps the most striking difference between it and the usual glaze is the very abnormally high content of soda and the correspondingly low content of potash.

We took some ordinary seven-inch plates from stock and after dipping in this glaze we fired them in the glost kiln in three saggers, 5, 8 and 13 high, respectively. These saggers were fired in the second ring, which is our usual practice.

I should say that the absorption of the biscuit ware varied from 7.5% to 9%.

These were placed with one stack in each of the saggers, and a second stack in each case with similar ware was dipped in the regular glaze. But when the kiln was drawn, I was amazed to find that in every single case the plates were twisted in the most extraordinary fashion.

The peculiarity about it is that the second stack dipped in the ordinary glaze and fired in the same saggers was perfectly straight, and so also was the ware through the rest of the kiln.

To confirm that, I took another series of plates and repeated. Conditions were exactly the same; but in this case the glaze was matured a little better; the fire was a little higher. The plates were very much straighter although they were still warped.

On the very crooked ones the glaze was by no means matured. In the second series they were still underfired but more matured than the first.

It must be that the warping was due to the glaze, since it was the only variable, and I was at a loss to explain the action to myself. The only explanation that I could find for this was as follows:

At the time the body is in the glost kiln the body softens slightly and when the kiln begins to cool, if the glaze solidifies before the body has become entirely rigid, the contraction of the glaze might be sufficient to pull the still soft body out of shape.

This explanation is not convincing; it does not entirely convince me. I have spoken of the occurrence to a great many ceramic friends but none could even suggest an explanation or had ever seen anything of the sort before, so for that reason, I brought it before the SOCIETY in the hope that some of the members may have had similar previous experience or may be able to suggest a better explanation than my own.

There is just one other point I would like to mention. If my explanation is correct as to the cause of the warping it would seem probable that the glaze (on the first series especially) would be in a state of high tension, and therefore very liable to craze, especially as it is immature. But that is not the case at all. That glaze has not crazed after heatings to 200°C, with intermediate dippings in water at 15°. That seems to knock my idea.

In the second series of experiments, although the glaze is better matured and there is less warping, the ware is much more liable to craze, and invariably the piece is crazed on the second dip.

I leave it now in the hands of the members, and I shall be very glad indeed if anybody can suggest an explanation of this thing which has puzzled me for a long while.

SEBRING, OHIO

Discussion

E. SCHRAMM: Mr. Riddle, did you not do some work showing the effect of the glaze on tensile strength?

F. H. RIDDLE: That was making small tensile test pieces and glazing them with different types of glaze and determining the strength. With a glaze that fits the body the strength is materially increased while with a poor fitting glaze the piece would show a much lower tensile strength than the specimen with no glaze on it whatever, indicating that in small pieces the fit of the glaze is very important, also making a very nice method of determining which glaze really fits the body best. That, though, does not explain the drawing or pulling that the glaze must be doing in Mr. Shegog's case.

A. S. WATTS: It may just be a coincidence, but in the plates that have passed through my hands in the last few minutes, I observed that the warped plates all are distinctly yellow. Now I can only interpret that in one way, so far as my observation of this problem goes, and that is that the warped plates in the bisque were not fired as hard as the straight plates. Did you make any determinations to know what their porosity was?

T. A. SHEGOG: They are all between $7\frac{1}{2}$ and 9% absorption.

A. S. WATTS: If the yellow plates were more porous warping might occur from the soluble salts in the body, absorbed from the frit. I think it is worthy of very distinct consideration that all of these plates that are straight are much whiter than the plates that are warped.

T. A. SHEGOG: I think that must be purely accidental. The plates used for both series of tests were taken at random from stock and the glaze was the same batch; all were dipped in the regular way.

A. S. WATTS: I am not offering this as a solution—it is merely an observation. Why are the straight plates white and the crooked plates cream? I have seen instances where the presence of a certain amount of soluble salts in a body developed distinct warping when they came to the last stage of firing, and I merely make that as a suggestion which may throw some light on the problem.

S. RUSOFF: With reference to the tensile strength, some few years ago we had considerable warpage and in making an absorption test of some of the glazed tile, the same sized tile, I noticed quite a difference in the absorption between the straight tile and the warped tile. With this thought in mind, a set of trials were made using the same dust but giving a portion more pressure. Firing the trials at the same heat we found a considerable difference in the warpage of the tile. The more compact the body the less warpage we had to contend with.

CLAY STORAGE[1]

BY ROY A. HORNING

Advantage, construction, equipment and operation of clay storage for brick plants are related.

Clay storage is a worth while consideration by any one interested in the manufacture of heavy clay products. The trouble has always been that most heavy clay products such as brick and tile can be made without it. However, it seems to me that more and more this subject is finding its way to the attention of the progressive manufacturer and if the benefits to be derived from it are fully understood there will be more storage facilities built.

Perhaps the best recommendation for the clay storage is the man who operates one that is properly designed. However, there are many who do not have one and are not familiar with its advantage. The advantages of a clay storage can be divided into two classes, the two overlapping to a certain degree. (1) Complete unification of clay digging and preparation. (2) More uniform mixing of the clay.

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Columbus, Ohio, Feb., 1925. (Heavy Clay Products Division.)

(1) What does complete unification of clay digging and preparation mean? It means operating your clay digging and preparation as a separate and distinct unit. How many employ power shovels? How many see every day a shovel capable of digging two times, three, or even four times the amount of clay that the plant actually uses? The clay storage makes it possible to utilize this extra capacity to a better efficiency. If it is possible to dig sufficient clay in four hours to operate ten, why not do it?

This allows that particular unit more flexibility in operation as well as many outstanding economies in labor and overhead. How often have you seen a steam shovel, four or five men, a locomotive, in fact the entire clay digging equipment stand idle for an hour waiting for some one to make a minor repair in the mill? Likewise, how many times have you seen twenty-five men waiting for clay to come from the clay pit? Now would it not be better to have a clay storage in between these operations? That is where a direct economic saving can be effected. The wages of one or two men operating a clay storage will more than be offset by even a few hours loss of production.

Have you ever seen days during the winter when you yourself would not think of wanting to be out; yet you must have the pit crew out if you want to make brick on these days. Humanity has some rights even in a clay plant and this phase should be given consideration. It is possible with a clay storage of proper design to choose to a certain extent the days on which you dig clay. This not only proves a saving in the cost but also may save many a delay due to wet, frozen or icy clay. I visited a clay plant last year whose capacity was 100,000 per day. I visited them during a rainy period of a few days; their production had dropped to less than 40,000 per day. The feeders would not feed their clay in such a wet condition. A clay storage would have been a life saver for this plant. One-half mile away another plant was working, making 110,000 per day, had a clay storage and made their capacity each day. In one case the clay pit men were sliding and slipping around the pit trying to get a little clay dug, in the other case the pit crew was repairing their equipment. Which of these two was the gainer?

There is always much work to be done as an accessory to the actual digging of clay such as stripping, shooting, moving track, etc. How many plants employ a separate crew of men for this work, where if the full capacity of their digging equipment was utilized, enough time would be left to take care fully of a great portion of this extra work. I do not say that in every case clay pits are run inefficiently. I only know what I have seen and I might say I have seen very few which were efficient even up to 50%.

Some plants find it necessary to operate with a mixture of two kinds of clay and in order to do this have two complete crews of clay pit men, one

for each pit. This often can be reduced to one crew by using them at one pit one-half day then moving them to the other for the rest of the day, putting the clay in the storage; and by proper distribution it can be mixed even better.

(2) The advantages pointed out so far are purely economic. Nothing has been said about the improvement of the ware. Quality of finished ware begins at the clay pit. Rarely if ever will a clay pit run uniform from the top to bottom, or from end to end. The variation may even be so great that two successive hours running will not produce the same clay. However, if an average of a day, week or month could be taken, it would be found that a composite sample of the clay would be about the same from day to day. Thus, by using a suitable storage, the clay could be so mixed that a very uniform run could be secured.

Much of the trouble in heavy clay products can be traced back to the variation in the clay from hour to hour or day to day. Clay dug and rehandled through a storage seems to act entirely different from clay dug directly from the pit. This is due to several reasons. The moisture content of the different strata of clay becomes uniform. There are small lumps of dry material and some very moist. When these are put into storage the clay with the most moisture will yield to the absorption of the less moist and in addition to this there is much evaporation. The fact that the clay lays for some time ages it to a certain extent, apparently making it work more uniformly when used.

By proper distribution of the clay in the storage shed any desired mixture can be obtained. This question of distribution should be carefully guarded as it is very easy to put clay into storage and take it out exactly as it was put in, effecting very little mixing if any.

What value can be placed in the storage shed as a mixing proposition? This depends entirely on the character of the clay put into it, also the preliminary preparation that has been put on the clay. Clay should have some preparation before going into the storage shed. It should never be stored, in my estimation, as it comes from the bank. Clay coming from a bank as a rule will have a great many large lumps in it. These lumps should be reduced to a small size since there is a tendency for lumps to separate from smaller material when dumped into a pile. Better yet, all the clay going into storage should be prepared for its final use if possible to do so. That operation being done the grinding unit can work independent of the manufacturing units. Sometimes it is advisable to have the storage divided into two divisions: one to care for a reasonable amount of freshly dug clay, then after grinding to its proper size, another larger storage for ground material. This may prove to be a decided advantage in some cases, and especially is this true where fine grinding is required. It may be an economical arrangement to run the coarse grinding plant along

with the digging, setting up a fine grinding unit to run 24 hours per day. There is much room for improvement in the matter of digging, handling, preparing and storing of clay. Many economies may be effected and many improvements may be made in the qualities of the finished product before any real manufacturing is begun.

Types of Clay Storage

Plant requirements should be studied with utmost care and a storage built that will meet conditions of each particular plant. Its design depends, first, upon the nature of the clay, second, on the amount of storage needed, and third, the conditions in which the clay is to be stored; clay storage systems can be made to cost whatever you desire above a minimum amount. Just how many refinements you care to put in them regulates largely what they cost. I have seen storage piles entirely exposed, clay being piled up by cranes and being removed by steam shovels. I have seen them piled by cars and removed by cars, piled by belts and removed by cars, and vice versa. However, the most successful ones use belt conveyors to put it in and belts to take it out. Conveying equipment costs

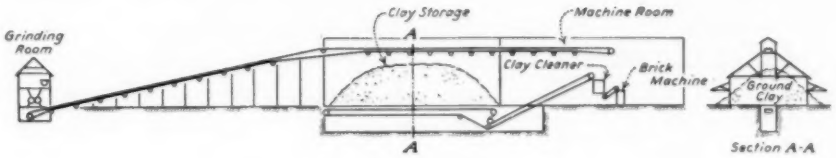


FIG. 1.

money and much money can be spent or saved by properly designed clay conveying equipment.

For instance, a conveyor designed to handle large lumps of clay will require a wider and heavier belt than one designed to carry ground material. A 24-inch belt costs $33^1/_3\%$ more than an 18-inch belt, and an 18-inch belt costs 50% more than a 12-inch belt, etc. Not only do the belts cost more but wide equipment costs more than narrow. This phase should be thoroughly studied to determine the most economical size and speed.

Last year we built and equipped a clay storage system that I am going to describe briefly. This system stores ground clay ready for use and consists of an overhead 18-inch belt running on a steel slide. Running in an opposite direction is a moving scraper, which acts as a distributer. The height of this belt is 30 feet above the bottom of the storage; it passes through the middle of an open-sided shed 60 feet wide. This allows us to pile clay 25 feet high. Allowing the clay to run to its natural angle of rest makes a pile 60 feet wide. The speed of this moving scraper is ar-

ranged so that it will pass over the entire range of the pile for each car load of clay. As an example, you want to distribute the clay over 100 feet. A car load of clay requires 4 minutes to grind, then your scraper should pass over the full 100 feet in 4 minutes or travel at a rate of 25 feet per minute. That means that each car will be distributed over the full length of the pile. The power required to pull this scraper at that speed is very little. It may be run directly off the conveyor belt or driven independently by a motor.

Through the center of this building below floor level is another conveyor running on steel plates; this conveyor is covered by means of a wooden plank about 12 inches long and 8 inches wide. As the clay is worked out the planks are removed and the clay dragged in by a hoe. This gives a cut through the pile which at an angle of 45° on each side of the center leaves the side stand. This makes available a section of about 312 square feet or about 312 cubic feet of clay per foot of shed. If trimming is needed it is very simple to run the sides in by means of a portable conveyor.

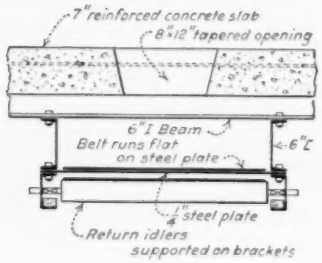


FIG. 2.

The conveyor for moving the clay is a 24-inch belt running on steel plates. This makes a dirt proof conveyor. No clay can spill into the pit below the pile. The return idlers can be bolted in the bottom of the steel trough which makes a very neat and clean conveyor pit. The cover for the conveyor pit is a 7-inch reinforced concrete floor and the conveyor trough is bolted to this floor thereby doing away with all posts or frame work for the conveyor.

This particular storage shed cost with conveyor complete is $4500.00 and will hold enough of clay to make 1,000,000 bricks. One man will remove sufficient clay if it is ground for 8500 bricks per hour. This storage was put in with the clay grinding plant behind it so that we are really storing the clay and taking it out with no extra men as by moving the grinding units we saved one man. This particular system might not be adaptable for another plant. Before building a storage the whole proposition should be surveyed to find out what is most practical. The system just described might be termed the open shed system where the clay forms its own retaining walls.

A much nicer but more expensive system can be built using concrete retaining walls and sloping floors whereby all the material can be reclaimed. However, as I have stated, each individual problem should be taken up and solved to meet the individual needs.

In the system just described the overhead belt runs over the clay shed and continues on to the pug mill so that at any time the clay can be passed

right on to the machines and not go through the storage. An elevator at the reclaiming belt elevates the material back on to the overhead belt going to the pug mill. The cost of operating this shed as far as labor is concerned is no more than our former system. However, the charges on the equipment run up an item of expense which as near as we can tell amounts to about 15c per thousand. This cost would depend a great deal on the production. In our case it is based on 10,000,000 per annum. However, when the saving in production and quality is calculated, a clay storage can easily pay its own way in every respect along with a dividend on the investment.

We desired to allow our clay to dry to a certain extent. That is really why we built an open-sided shed as shown. Being open with steep roofs the circulation of air is very rapid giving a great deal of drying effect. This is perhaps as cheap a shed as can be built as there is very little to it but a roof.

One should bear in mind that no wood should be used where it will be in the clay, for sooner or later it will rot. The shed that I have just described has no wood below the roof trusses; it is all steel and concrete.

The object of this paper has not been to give any unique system of clay storage but rather to bring a little more thought about its use and advantages that we may make better ware. I have tried to bear in mind that I am not recommending any particular type of storage as that should be designed for each individual plant to meet its own peculiar needs.

LANCASTER BRICK CO.
LANCASTER, PA.

PLANT MANAGEMENT METHODS[1]

BY O. J. WHITTEMORE

Statement of the Problem

Methods used in the management of heavy clay products manufacturing plants must necessarily vary with the circumstances and conditions peculiar to each individual plant. As it would be impossible to discuss different methods of handling similar operations all the way through the complete process, I will discuss principally those methods which at present are most familiar to myself; those which I have developed and used in the management of the two plants of the Sheffield Brick & Tile Company, located at Sheffield, Iowa.

In the past several years, the business depression in our territory, Iowa, Minnesota, Nebraska and South Dakota, has affected our business enough so that one plant's production is sufficient to take care of the needs of the trade. This condition has made plant operation more difficult, as

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, February, 1925, Columbus, Ohio. (Heavy Clay Products Division.)

all of our many varieties of shapes and sizes must be made at one plant and on one machine, where otherwise, one class of shapes could be made at one, and the other class at the other plant. The difficulties from this forced manner of operation are obvious. My paper will cover more particularly the subject of maintenance of production in one plant producing a wide variety of wares.

We manufacture all the sizes of drain tile from 4 to 12 inches, inclusive, common brick, smooth and matt-faced face brick, common building blocks, matt-faced and plain load-bearing blocks, the accompanying items of jamb, corner and sectional blocks, partition and floor blocks from 3 to 12 inches in width and furring blocks.

The difficulties incident to plant operation with these conditions are divisible into two classes, namely, those affecting the men, and those affecting the equipment. Changing of the men from one ware to another slows up their efficiency at the time of change. The changes necessitate many additional dies, cutters, machine heads, spacers, texturing machines and pallets, and these cause much loss of time and effort, as well as large investment. The bulk of clay to be dried varies with the different shapes, and different humidites and temperatures must be used. Differing procedures of setting and firing must be used at the kilns, and several methods of emptying with the different wares.

The problem of maintenance of high production is somewhat similar to that of a heavy freight train, after slowing up for station stops, momentum is lost and much additional power must be used to regain top speed. In this clay plant, the practice has been developed so all of the men help, in the transitory periods, to pick up the lost speed.

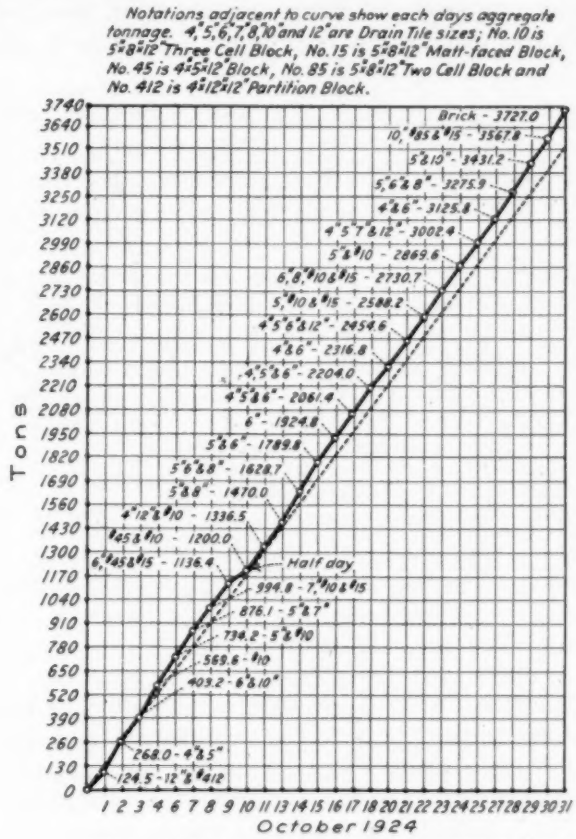
Piece Rates and Bonus

To get full measure of coöperation from the men it is necessary to provide for their wages and their morale. Their wages are established on a piece-rate basis, as much as is possible; the wheelers are paid per ton, or thousand of brick, the rates differing with the different wares; the setters per car of ware, the rate again varying with the kind of ware. The coal is unloaded and placed at the kilns for so much per ton. The kiln cleaning, casing, repair and sanding is contracted for a flat sum. The men connected in the machinery rooms and those in the pit, machine tower, drier and the transfer men are paid on a flat hourly scale, with tonnage bonus at the end of each month. The kiln firemen are paid on an hourly basis, on a merit system.

In addition, all men receive a bonus on the first of December for continued satisfactory service throughout the preceding year. This is dependent upon their remaining steadily with the company. This cuts down the usually high clay plant labor turnover. This bonus is figured

at so many cents per ton, thousand of brick, car of ware, or ton of coal handled by wheelers, coal handlers, or setters, as the case may be.

Besides all these forms of remuneration, we usually present each man with some sort of remembrance at the Christmas holiday season, and this year, we took out group insurance, a policy for each man in the company's employ. These policies are increased in amount with additional length of employment so besides having the effect of Christmas remembrances, they also are the yearly bonus for continued service.



Boys! Make that bonus with Good Material!
Keep the actual tonnage line above the dotted one!
A suitable compensation will be made to all men if we pass the goal of 3510 tons October thirty-first.

FIG. 1.—Production record, Oct., 1924.

Maintenance of Morale by Charts

For the maintenance of morale, a bulletin board is used. Charts are used to picture the progress of manufacture, setting a goal of monthly

production, and showing the actual accomplishment from day to day in a line of one color as against the desired tonnage in a line of another color. This is shown in Fig. 1, the dotted line showing the progress as desired and the black line, the actual attained tonnage, added day by day to the total previous tonnages. The establishment of this goal, and the attempt at attainment, makes an element of interest to offset the monotony of the never-ending repetition of tasks, and arouses their sporting blood, the great American love of contest.

We have several forms of charts, the monthly chart, already described, the daily chart and that for the whole year. On the daily chart an ex-

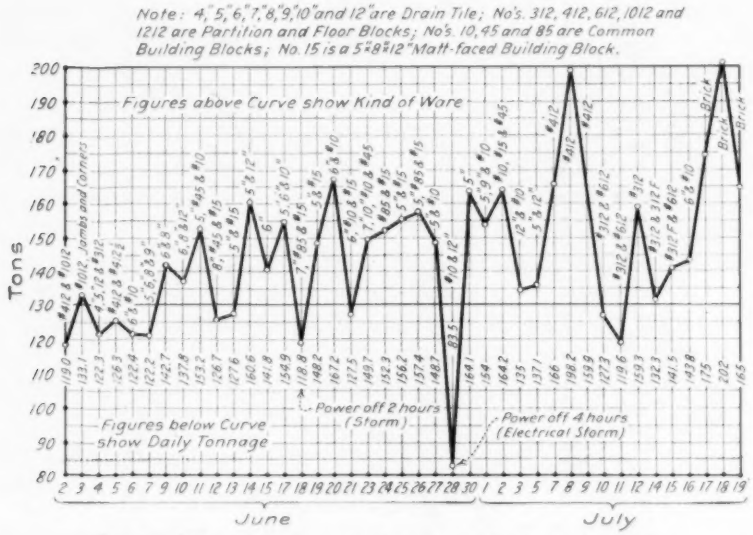

Note: 4", 5", 6", 7", 8", 9", 10" and 12" are Drain Tile; No's. 312, 412, 612, 1012 and 1212 are Partition and Floor Blocks; No's. 10, 45 and 85 are Common Building Blocks; No. 15 is a 5"-8"-12" Matt-faced Building Block.
Figures above Curve show Kind of Ware
Figures below Curve show Daily Tonnage
Power off 2 hours (Storm)
Power off 4 hours (Electrical Storm)
Tons
June
July

FIG. 2.—This chart shows each day's production separately.

ample of which is shown in Fig. 2, the daily results are shown separately, there being a horizontal line, picturing an average tonnage, and the accomplished tonnages forming a series of ups and downs, accentuating the low and high attainments. On this sheet, we make notations to show the men if the results, whether good or bad, are directly traceable to any particular department or individual, or due to the limitations imposed by the particular type of ware. On the illustrations are noted the kinds of ware made each day, but this is not shown on the actual charts.

The charts and notations arouse the men's interests, start them to thinking where they can help, stop much of the grumbling and discontent, and give them something to talk about, in connection with their work. The results in greater tonnages of good ware are well worth the extra effort.

Special bulletins are posted calling the attention of all the men to the

need, if results show that one department is lagging. These bulletins are in addition to instructions made directly to the department heads. Compliments as well as corrections are noted on the bulletin board, so that none may think we are continually nagging, with no appreciation of their efforts. These bulletins are supplemented by frequent group conferences of the department heads. At these meetings, past performances and future procedures are discussed, and the departmental efficiencies are brought to light so mistakes can be corrected and improvements made.

A complete plant cost system is kept and at the end of the month, a summary of costs, production and shipping records is made. Some of these results are disclosed at these group conferences. Discussion of the relation of production to costs, emphasizing the large increases in costs as they accompany shrinkages in production, whether daily, weekly or monthly, has been very beneficial to the foremen but we would not consider it wise to discuss these things with all of the employees.

Attainment of a charted production goal is rewarded in various ways. Most of the men who are not working on a piece rate basis are given in addition so many cents per ton production in excess of the established goal. This is a definite reward, offered every month, but in addition to this, we have given them special prizes, such as dinners, picnics, entertainments and movies, all of which tend to maintain interest, on account of the novelty of the ideas.

Description of the Plant

Gathering the Clay The common pit for both plants has a face of 34 feet of Devonian shale. This is gathered by a shale planer, supplemented by a steam shovel for cleaning up the wedges of clay left by the planer. The planer can be operated so that it will clean up for itself, but it is not economic, since it necessitates more frequent moving of the planer, and less efficient cutting duty.

A large, deep drainage system around the pit cuts off the seepage water which in the spring formerly caused cave-ins, and in the winter caused the bank to freeze harder with accompanying bulges, all of which made the planer duty much more severe, with many mechanical break-downs, higher maintenance cost and smaller production.

Clay Preparation and Manufacturing The clay is hauled from the planer by a drum and cable hoist to a central station, where cars can be dumped into hoppers which empty into other cars going to either of the two plants. In the plant, the clay dumps into a hopper, from whence it is worked out through a granulator or heavy pugmill. Since the advent of the planer, the granulator's duty is much easier as the clay comes to it in much smaller pieces. Water, hot in the winter time, is introduced at this point, and then the clay runs through a

set of conical rolls, which remove the small quantity of soft sand rock, and also do all the grinding necessary for the soft shale. The clay next goes through two separate pug mills. It then goes into an auger or stiff mud machine, through dies, to automatic cutting tables, thence to the off-bearing belt, and from there is placed on double deck drier cars.

This machinery is housed in a five-story fireproof building of brick, steel and concrete. The clay movement is entirely by gravity, thus eliminating troublesome elevators and conveyors.

The plants are electrically driven, the "juice" purchased from a high-line company, on a sliding-scale rate. A large motor is used to drive the line shaft from which drives are belted to the granulator, rolls, pug mills and auger machine. Individual drive is used elsewhere. The line shaft runs in ball bearings as also do two of the larger motors. Three of the larger drives are chains, and the rest are belts.

Drying Drying is done in twenty-four-track waste heat driers, with fans at both ends. For heat additional to that furnished from the cooling kilns, an auxiliary furnace has just been added at one plant. These driers hold approximately 400 cars apiece, and have stub track space at both ends so that the driers can be worked 24 hours of the day.

Firing There are at one plant 12 round down-draft kilns, 30 feet in diameter, steel-shelled, with triple draft bottoms, and checker work floor; and 16 kilns, 9 of which are 26 feet in diameter, and 7 are 30 feet in diameter and steel-shelled, at the other plant. At the newer plant, the 12 steel-shelled kilns have only the one 150-foot smokestack, while at the other there is one 65-foot stack for every four kilns. The one large stack is considered to be an improvement, as there is always sufficient draft, even for water-smoking, and there is no tendency for one kiln to rob another of its draft.

Placing the kilns in one row with a single stack, necessitates the use of an electric transfer car to take the ware speedily from the drier to the setters at the kilns.

Scheduling of Plant Flow

Much planning and careful supervision must be given to produce quantity and quality. It must be continually emphasized that the operation of machinery must be punctual and continuous; that small delays be eliminated, for they total into large leaks. Schedules for manufacture of ware of particular groups are established and followed as much as is possible. Occasionally with large rush orders, balanced stocks will be affected so that changes in plans have to be made.

It is better practice to make nothing but one class of ware during a certain period, and these periods should preferably be long. Large shapes are

preferably made when large shapes are being set and fired as the plant rhythm is thus better maintained throughout. Long runs of brick are most productive but in case of shortages in stock, by operating on brick on Friday and Saturday, the extra day, Sunday, when the drier is not worked is sufficient to give the extra drying the brick require. Changes of machinery, etc., can be thus made on Sunday.

When slower drying and setting ware is being placed in the kilns, slower machining stuff is made, thus keeping a better balance between setters, drier and machine. Schedules are made so as to permit the changing of dies, heads and cutters, at the noon hour, in the evening or on Sunday. An exception is made to this rule with most sizes of drain tile, as these dies can be changed in ten or fifteen minutes. Wherever possible, the schedule is arranged so that the heavier wares will be going through the drier when heat is available for the drier from kilns containing heavy wares. The more tender wares, which are more difficult to dry are scheduled for manufacture when the drier is foreseen to be in better shape to handle them. The heat and humidity conditions of the drier must be manipulated to correspond to the particular ware to be dried. Often the tender drying wares are made on Saturday, or on a day before a holiday, so that their movement through the drier will be postponed a day and thus allow for the needed slower humidity drying.

Drying Control A recording thermometer shows the temperature in the main inlet tunnel to the drier. This is supplemented occasionally by use of a hygrometer to check humidity conditions in the cooler end of the drier and to set the exhaust dampers to balance the exhaust from the individual tracks. There are various other controls on the drier, such as a relief stack at the hot end to cut down the temperature when excessive, and still be able to cool hot kilns where shipping needs require the prompt emptying of these kilns in the summer time.

Where the temperature is too low, the auxiliary furnace is pressed into service. Where higher humidities are required for certain wares, a slackening of exhaust is effected by opening additional air ports to the exhaust fan, reducing exhaust damper openings, or, in drastic conditions, by shutting down the exhaust fan entirely. This is not desirable for some wares on account of the danger of scumming if the exhaust is cut off too long. The stub tracks allow the 24-hour operation of the drier, and this increases the drier output and cools the hot ware in time for the setters each morning in the summer time.

Firing Control An Indiana fifth vein nut coal, $1^1/_2$ by $2^1/_4$ inches, shipped on a steam coal freight rate is used in the kilns. It is a long flame, gassy coal, with medium fluxing clinker. The kilns are pyrometrically equipped; an indicating instrument being avail-

able to the burners, and a recorder in the office. Most of the ware is fired with reducing conditions throughout the main part of the firing. Some wares, where a light clear color is desired, are fired with as much oxidizing atmosphere as is possible with slant grate fireboxes. The finishing temperature is approximately 1800°F. The firing records show the average firing time, including watersmoking, to be 48 hours with an average coal consumption of 390 pounds of coal per ton of ware.

Close attention is given to the cleaning of the bottom of the kilns, and with this done, uniformly fired ware from top to bottom, over the whole cross-section of the kiln, is accomplished in our steel-shelled, triple draft bottom kilns. Dirty bottoms are the cause of loss in many ways: greater fuel consumption, slower kiln turnover and poorly fired ware, which must either be waste or sold at a loss.

Slugging of fires, with greater firing intervals, as the average fireman will operate, is another source of loss, as kilns will progress slower, have higher losses of poor ware and cause higher coal consumption. To offset these and other tendencies on the part of the firemen, various bonus schemes have been worked out, whereby crews of firemen are given merits for lower coal consumptions and higher than average percentages of No. 1 ware, while demerits are given for the opposite results. At the end of the month, these merits or demerits are balanced and the firemen's pay checks increased or decreased accordingly.

A separate bulletin board is kept for the firemen, and on this, a daily record of demerits or merits is kept for all kilns as fired off and emptied. A rivalry is set up between crews to get the higher record and comments are made on the bulletin board to agitate this rivalry. At first, there was a tendency for crews to present alibis for poor results, such as kilns being dirty, different coals being given them, or different setting of ware, but by being sure that kilns were kept clean, using a uniform grade of coal, preserving uniform conditions as much as possible and maintaining an uncompromising attitude, the crews soon worked into the idea and better results were soon forthcoming. Kilns come off regularly and the whole plant operates more like clockwork as a result.

Control of Quality

Much emphasis has been given so far to quantity production, but quality is not overlooked. A very careful watch is given this as well. There never was a time when clay products manufacturers were competing any more bitterly for business in this territory. All manufacturers are trying harder than ever to make extra good ware. Customers are expecting better material and object very quickly to any let-down in quality. The men all throughout the plant are constantly cautioned to maintain the superior quality of Sheffield Clay Products. They are shown

where they have their individual responsibilities in this accomplishment. The pit men are coached to keep out impurities such as large rock, roots, weeds, etc., the machine men to keep the rolls grinding fine and steady mixtures in the pug mills. The dies are watched closely so that no change will occur in the positions of cores, etc., thus causing differential flow of clay and the accompanying reduction of quality and increase of imperfect ware which must be rehandled. The off-bearers have their machine room foreman watching them constantly, and they are trained to handle the ware carefully, reject and throw back into the waste conveyor all cracked, bruised and deformed pieces. They are constantly given to understand that they are responsible for the right start in life of all the material and that they must not be careless.

The transfer men, drier man and setters are likewise shown where they can assist. The firemen profit when they make better ware, as was previously described. The wheelers are continually warned against excessive rush, rough handling and poor sorting. When complaints come from customers as to quality of ware received, and especially as to excessive breakage where it has not been shown to have been railroad negligence, a conference is called of all of the loaders and such communications, as well as the complimentary letters, are read to them so they can get the viewpoint of the company and the customer requirements. In furtherance of this same idea, occasionally when complaints come in, the loading foreman or superintendent goes to the point in question, and gets a close-up of the situation; tries to determine in his own mind whether or not the complaint is justified and makes adjustment when necessary. On his return to the plant he calls a meeting of the department heads if it is a point needing the attention of all, or otherwise a group of just those particularly concerned in the need for improvement or change in methods.

No one system or plan of plant operation will fit all plants. Circumstances will alter the methods, but generally speaking, the principles of operation which we endeavor to follow can be used everywhere. In the handling of men, if the policy is one of fair play and justice to all, if the pay is reasonable and interest is awakened in their work through contests and schemes of various sorts, you are bound to have a satisfied loyal crew that will coöperate to their limit to produce both quantity and quality. Augmenting this policy toward the men, if the equipment and machinery is handled through scheduled and thoughtful operation, planned to eliminate delays and to get the maximum results for the effort extended, your clay plant manufacturing troubles will soon cease to be erratic and resolve themselves into a smooth, clock-like precision that makes for the elimination of the term "game," as applied so long to our industry, and puts it on the higher plane as a real bona fide business.

Sheffield Brick and Tile Co.
Sheffield, Iowa

DRYING, DRIERS: THEIR OPERATION AND CONTROL

By M. W. Blair

Introduction

A road often traveled is seldom familiar. A tree, a house, a sharp turn suddenly comes to our notice and we wonder if it has been there all the years we have passed that way day after day. So it is in the manufacture of heavy clay products. We follow the same road for years, then our attention is called to some oversight, some lost motion in the process, or an obviously ridiculous method, and we wonder if it has been there all the time. Usually it has but often it has crept upon as unaware through neglect, habit or ignorance.

This tendency to pass by without seeing is one reason for repetitions in our programs and discussions. Everybody does not wake up the first time the alarm is sounded or the loss pointed out. With the passing years there is constantly a new crop of foremen, superintendents and engineers and to them the past experience of many is a new adventure and the problems new.

The property of air to carry moisture and the power to absorb it from moist bodies, is the basis of drying of clay ware. The ability to obtain the most drying power at the least cost is the problem of the designing and operating engineer. The problem seems simple to the uninitiated but in practice, it is complicated, wasteful and one of the least understood. Internal strains, causing ware to check, crack, blister, twist and warp and scum producing gases are some of the problems connected with drying.

It is not the purpose of this paper to cover all of these problems but to bring attention to a few causes of failures in the operation of driers and to suggest methods for increasing quantity and quality production and for lowering of cost. Our big problem now is not to design a new drier but to get the most out of the driers we have and to make them earn money.

Drier Faults

Most of our driers are designed to be progressively operated, *i. e.*, of the tunnel type, admitting green ware at one end and removing it dry from the other. Few driers of this type are working in a satisfactory manner. Capacities, in most cases, have been over-estimated and the plants are few that do not set toward the end of the week some wet ware.

One mistake of operation is the attempt to crowd into a period of six or seven hours what was intended to be accomplished in twenty-four hours. Ware which has been in the drier a period of thirty-six hours has not necessarily received a proper drying treatment. A car of brick made at 7 A.M. is often the fourth car from the door by 2 P.M. Under such conditions, it has received mighty rough treatment in the early stages and has

then been over-dried for hours before being drawn. Those cars drawn later are often over-dried on the top deck but still steaming on the bottom courses because the setting crew is permitted to finish its day around 2 P.M. The entire day's output is through the drier by that time. In many plants the day's run is also finished and the drier is put to sleep for the night, a long night too, for it stands idle sixteen hours out of the twenty-four.

The first four cars which are over the heat have finished drying in the course of four to six hours but the heated air from fan or furnace continues to pour through the already dry ware. The humidity of the air then drops, its temperature rises, its velocity increases, and away go the heat units over the top to the stack and out.

Advantage of Continuous Operation

All sorts of devices have been introduced to overcome this difficulty, bottom draft at wet end, either to stack or fan, curtains, deflectors, pressure and recirculation. Verily, laziness is the mother of invention but the wind, even in a tunnel drier "bloweth where it listeth and no man knoweth whence it comes or whither it goeth."

The common-sense cure is to draw and charge the drier over the entire twenty-four hour period. This can be done by working the setting crew in shifts and providing empty car storage. Continuous operation hastens the kiln turnover. The ware being uniformly dry, not red hot and bone dry in one spot and little better than mud in another, reduces the drier loss, lessens scumming, kiln marking and production of bats. It also shortens water-smoking periods and increases the percentage of No. 1 ware and the kiln output.

This suggestion applies to any progressive type drier. It will apparently increase the cost of drier operation but it will decrease the cost of ware per ton because of better quality and increased production. The machine crew will have a supply of empties. The setters will be able to take more time and consequently more care and can work more efficiently. The closing of a kiln will not be the cause of loss in output due to slow setting

Temperature Control Important

The regulation of heat by a look at the fire, by the feel of a door, by spitting on the fan housing, seems a silly proposition on a plant with an investment of almost $100,000.00 when proper regulation of drying and firing means the difference between a profit and the sheriff, but they are by no means uncommon. We have some remarkably good guessers in the industry but the man who guesses at temperatures also guesses at his bank account.

The Booster Furnace

The booster furnace on waste heat driers is the offspring of slow kiln turnover and poor regulation. It may and should be eliminated. It is possible,

in most materials and products, to turn a 28 x 32 foot kiln twice a month. If that is done there will be little necessity for the booster furnace, with its soot and sulphur, or the absurd expense of coke or blacksmith coal for its firing.

Kilns are sometimes allowed to stand twenty-four hours to rid them of sulphur fumes, an unnecessary loss of time if the ashes and clinker are removed from the kiln while still hot.

The final heat should be removed from the kiln by a cooler or goose neck to the crown. A kiln at 500° to 600° is of little benefit to the drier but is often left on to cool the drawing crew and the booster fired to make up the difference.

Waste Heat Driers not Economical

It might be considered reactionary to recommend the elimination of the waste heat drier for the sake of economy and better product. We are divided between two schools, one of which would make the entire plant a synchronized unit and another which would make a unit of every piece of equipment. The waste heat drier works neither way.

A direct-fired, radiated heat drier will work as a unit or will synchronize and is much more easily controlled in temperature and circulation. It obviates a large percentage of objectionable fumes in contact with the ware, preserves equipment from destruction and operates without power. Against these advantages are the items of fuel cost and labor of attendance, both of which seldom exceed fifteen cents per ton.

The more drier operations I observe and the more I contrast the results obtained by the two types, the more I am convinced that waste heat in drying is a misnomer and that it actually is waste, no heat and little drying.

Driers Should Operate at Capacity

Driers are usually short a few cars to fill the tracks and stubs. This is a source of difficulty in operation and regulation, as it is impossible to obtain 100% efficiency from less than 100% apparatus.

These recommendations are not theoretical. They are in actual practice. For example, I have a record of drier operation where the trackage was increased 21% and the car equipment 34% resulting in an increase of 53.3% of dried product. That is, 90 cars per day were considered the limit and an average of that number had never been obtained, but with these additions and with care in regulation, together with the increased heat which was available, the output of the drier reached a daily average of 138 cars.

Many faults of design and construction exist, some of which can be corrected with little expense, others only by a new drier, but the ability to observe conditions and devise the remedy must be in the operator.

I have in mind a plant where sixteen tons per tunnel are dried and another where less than seven are the tunnel output product and material

are similar. I have also in mind a plant where it is said to be impossible to put dry press ware successfully through a waste heat drier, but the clay from the same vein is shipped one hundred miles, made into dry press brick and dried in a waste heat drier. I mention these inconsistencies to emphasize what I have often stated: that the industry needs common sense as well as technical research.

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HOW IMPROVE THE HEAT ECONOMY OF GLASS TANKS?

By S. R. Scholes

ABSTRACT

Less attention has been paid to furnace design than to glass-working machinery, because fuel cost has been a relatively small item compared with labor. Some of the suggested means for raising fuel efficiency are: ports designed to give a better mixture for combustion, and a better spread of the flame over the glass; insulation, wherever the refractories can stand it.

Until recent years, the cost of fuel for glass-melting tanks has been one of the lesser items of cost in glass manufacture. The tank itself is hardly a generation old as a device for melting glass, and its development was contemporaneous with the quantity production and prodigal use of natural gas. At the same time, skilled labor became increasingly dear, so that inventive effort was applied particularly to the mechanical working of glass, with pronounced success.

Accompanying glass-working machinery came increased tonnage, requiring the steady maintenance of high temperatures for its melting. In the last few years, natural gas has been largely replaced by other fuels, chiefly producer gas; and this latter fuel, because of the high prices of coal and labor, now costs more than the natural gas of pre-war times.

Therefore, although the fuel cost is still small in comparison with other items entering into glassware production, it is large enough to warrant earnest efforts at reduction. The efficiency of glass tanks is low. If 10% of the heat applied is found in the glass at its highest temperature, conditions are exceptional. Thus an increase of efficiency up to 20% would cut fuel bills in half, and any real improvement in furnace design or operation can show good returns.

Improvement could almost certainly be made in port design—to name at once that point where the gas meets the air, combustion begins, and the form and character of the flame is determined. We now simply provide holes in the side-walls, through which we alternately pour flame gases into the furnace, and remove the spent products of combustion. Where producer gas is used (and this is the fuel considered in the present paper) the mixing with air is poor. In some cases a stream of air sweeps

across the tank above the flame, not mixing with the gas or taking part in the combustion until the outgoing port is reached. This is obviously wasteful. Design that permits this faulty mixing is based on an exaggerated notion of the relative lightness of producer gas as compared with air. As a matter of fact, the specific gravity of producer gas is nearly unity. And when the air is hotter than the gas, considered an excellent condition for good combustion, the air often becomes specifically lighter. Then in a port designed so as to carry into the tank a stream of air above a stream of gas, flowing parallel, the mixing is bound to be incomplete. Some arrangement must be applied that will insure better mixing, so that complete combustion, a shorter flame, and no unused air beyond the small excess necessary for good burning, shall be the established conditions.

Better mixing will result in higher flame temperature, which is recognized as an aid to heat transfer. And of course the effective transfer of heat is one of the fundamental requirements for furnace efficiency.

Another change from the usual style of port that should improve the transfer of heat to the glass is to make the ports wide enough to cover a larger area of the tank with flame. Most tanks now throw across the glass narrow streams of flame, whose combined width does not make up half the length of the glass surface. Between streams there are areas of glass not directly covered by flames, receiving radiated heat from a greater distance and therefore less effectively. Spreading the flame to a greater width should permit the port openings to be shallower and the crown of the furnace lower, with less unused furnace volume.

But the greatest loss of heat in the present tank occurs through radiation. Clearly, since we must continue to heat the walls as hot as they are at present, this radiation would go on, regardless of more effective application of heat. Insulation is the remedy, but its application is limited by the endurance of the blocks and refractories. There is as yet a lack of data on the effect of insulating, for example, the crown of a furnace, which would seem to be the logical place to start covering against radiation loss. So far as the actual fusion temperature of silica brick is concerned, the cap should stand insulation, but it is somewhat uncertain what the effect of the alkali dust and fume from the batch might be, if the cap were insulated and therefore became as hot as the glass itself. There are advocates of block-insulation, but it will take time and step-by-step experimentation to determine what the results of this procedure, so diametrically opposed to current practice, will be. The insulation of checker chambers is an accomplished fact in many cases, with good results. The developments along the line of insulation in the next few years should be interesting to observe.

FEDERAL GLASS CO.
COLUMBUS, O.

GLASS AND REFRACTORIES SYMPOSIUM[1]

S. R. SCHOLES: Mr. Montgomery and Mr. Geller have presented excellent papers. In discussing the general theme of the attack of glass upon its retaining walls, I wish to bring up one or two characteristics that may be of interest.

A specific illustration of the difference in rate of corrosion, depending upon the position of the surface attacked, was recently presented when a tank that had been used nearly a year for pressed ware was tapped nearly free from glass before it was let out, leaving the walls exposed for examination. In the working end, certain channel blocks were set in the wall, flowing glass to feeders. These channels projected a few inches through the wall on the inside. One was examined in detail.

The corrosion of this inserted channel block had taken place almost entirely on its under side, that is, on a surface lying horizontally above (but immersed in) the glass. Here were found pits in the clay and "stalactites" of clay in varying stages of solution hanging from it. The clay had dissolved away, to the extent of about two inches from an original four-inch thickness. The upper surface of this channel block, over which at least 1600 tons of glass had flowed during its life, was smooth and scarcely attacked at all. (See Fig. 1.)

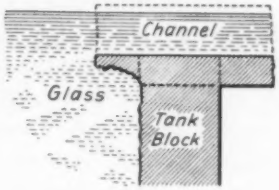

FIG. 1.

This behavior is just what would be expected, if clay with a true specific gravity of approximately 2.70 dissolved in glass having a specific gravity of 2.45, forming an argillaceous glass, or clay-glass solution, specifically denser than the original glass, and therefore inclined to sink in the tank as it formed on the surface of blocks.

By thus sinking and flowing away from surfaces facing downward, this solution would expose fresh surface for attack, and such surfaces, *i. e.*, facing downward, ought to be corroded more rapidly than upward-facing surface. On the latter, the formation of a clay-rich, viscous glass ought to serve as a protection against further corrosion, after a slight initial attack.

The same relative results may be observed when the bottom of a tank is considered, that is, how little it is corroded in comparison with the side

[1] R. J. Montgomery, "Present and Future Walls for Use against Molten Glass," *Jour. Amer. Ceram. Soc.*, **8** [4], 205–15 (1925).

"Developments in Glass and Glass Industries Refractories during the Year at the U. S. Bureau of Standards." Presented by R. F. Geller. Mr. Geller made an informal presentation of data. The paper has not as yet been released for publication. This Symposium was presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, February, 1925.

walls, particularly when we consider how rapidly the cover block of the throat is corroded compared with any other part of the tank.

Lately I observed a throat cover block that became a good deal more ruddy on top during a two-week shut-down, when no glass was flowing through the tank whatever, but the corrosion was taking place, and gradually letting it dissolve down thinner. It must be said, in all fairness, that the cover block being colder than the glass, we should expect the convection current to take glass away from it. It must also be said that the sidewalls being coated with glass would have the same convection current flowing downward. Therefore, I was particularly interested to note that in the tank which Mr. Geller described, the block which was totally immersed in the glass, had no cold outside, and showed the same corrugations where the glass flowed down.

In reading that portion of the paper, Mr. Geller mentioned the upward current, but I think here it is much safer to assume a downward current in the light of other experiences such as shown in Fig. 1.

There were several points in Mr. Montgomery's paper that I would like to expand upon a little bit. While saying that any refractory clay may be considered a glass pot clay, we may at the same time announce the opposing dictum, that all clays are attacked by glass. That is by no means an optimistic view, but it seems to me that that is exactly the view we are obliged to take, because we have not yet found anything, nor do I think there is anything, that we can afford to build into walls for retaining molten glass, that will not be attacked.

It is simply a question, as Mr. Montgomery pointed out, at the close of his paper, of proper compounding and constructing both with pots and blocks, to get the best results out of the material.

Glass is apparently an almost universal solvent for oxides. Inasmuch as we can scarcely hope to find substances other than oxides of which to build these walls, it is unlikely that we shall ever get anything insoluble. The principles governing the attack of glass on pot walls and tank block walls are practically the same, but there are one or two little differences that I can mention.

In the case of the pot wall, the fire is all over the outside. Therefore the pot wall is at all points along the side at any rate as hot as, or hotter than, the glass, so that any firing shrinkage that is taking place will tend to make the structure closer as we go from the inside to the outside. As corrosion takes place it finds a wall denser than the part eaten away.

In the tank block, on the contrary, we have the glass on the hot interior and the cold wall on the outside, so that if firing shrinkage does take place (if the block has not been fired to as high a temperature as it will ever reach in the tank), we shall have actual fissures open up on account of the firing shrinkage. And as the glass corrodes the block away it is always

meeting a more open structure than that which it has just succeeded in dissolving.

The point is made by Mr. Montgomery that we all appreciate that the tests of new block material or pot material take a great deal of time, and manufacturers are reluctant to undertake them. In that connection if the glass companies which we represent were only organized they could undertake these things coöperatively and a great deal might be accomplished with relatively small expense for any individual concern. I realize that certain economic questions are involved, competitive questions. Looking at it from a technical standpoint, however, it would seem to be an excellent thing to hope for.

In my estimation, the virtue of German pot clay lay, as the speaker said, in the fact that it was easily fired to a body of relatively low porosity. But that, we must remember, was at the sacrifice of refractoriness, and it would seem that it would be far better to do as Mr. Montgomery says we have unconsciously done, swing toward the more highly aluminous clays that are more refractory, fire them hotter, and secure this non-porous structure by means of heat in a refractory body, without making use of the more siliceous clay that has this lower melting temperature.

The corrosion of the walls by the glass is essentially a fusion process. One of the most striking things I ever encountered in work in chemistry, was in connection with a couple of organic compounds which were isomeric, but of different structure. One melted at about 25°C, the other at about 60°C. When we took a crystal of each and laid them together on a watch glass, the result was that they instantly fused. They melted by reason of the contact. A similar action takes place in a pot or against the wall of a tank block. The contact of two dissimilar and yet related silicates results in mutual lowering of fusion point, so that at the surface of contact we have a lowering of fusion point where it actually flows away and becomes a part of the glass itself.

In considering, then, the best wall for retaining glass, I am more and more inclined to believe that refractoriness is the prime consideration. What we want first of all is a wall that will not melt, and next we must have a wall that is not penetrated by the glass. The glass must not soak into it. We must avoid porosity. In order to get the requisite strength we are obliged to have a certain amount of flux in the clay. We are not going to succeed in building a satisfactory block or pot composed entirely of alumina and silica unless we go to extremes in the firing process. All of our satisfactory clays for such purposes contain what Mr. Montgomery mentions as fluxes. That is to say, principally such things as feldspar, and the alkaline content is usually taken as a measure of the feldspar content. The more alkali, of course, the stronger wall we shall have, the more easily the clay is fired to a strong body, but at the same time the more

we have sacrificed its refractory character, which may be held as the most essential property that the wall has.

J. L. CRAWFORD: It is interesting to note the methods used in arriving at the mixtures for making these refractories, as compared to the method suggested by Dr. Sosman.[1]

The refractory manufacturers would make up a number of tank blocks or pot mixes and actually test them out on a small scale, by methods such as that given by Mr. Geller for testing the resistance to corrosion. This method usually shows one mix to be slightly better than the rest, and this is the manner by which most mixtures have been, in the past, selected.

Some very good results have been obtained, and it is interesting to reason out a theory in support of these results. Mr. Montgomery brought out the fact that highly siliceous blocks or pots have been found to give very satisfactory results for certain glasses. We well know that siliceous clays are not as refractory as some of the more aluminous clays, such as kaolin, yet they have been found to be more resistant to corrosion. This is due maybe to the fact that kaolinite (Al_2O_3–$2Si_2O_3$) is not stable at high temperatures and that it quite rapidly breaks down to alumina and silica, then recombines at a temperature of 1350°C, forming mullite and silica. This later reaction takes place very slowly at the temperatures to which refractories are fired.

Examination of a commercial tank block, fired to this temperature, will probably show a very small percentage of mullite. When kaolinite breaks down into alumina and silica these constituents are in a form which react with the glass, far more readily, perhaps, than crystalline silica, such as is found in siliceous clays. We well know that a crystalline compound goes into solution more slowly than an amorphous compound, such as alumina and silica, set free from dissociation of the kaolin.

As I see it, according to Dr. Sosman's theory, a siliceous clay will more rapidly reach its stage of equilibrium under the heat treatment we now give tank blocks, and while such blocks do not entirely resist corrosion, they are corroded more uniformly over the entire surface, which means less rapid disintegration of the block and longer life.

No doubt there will be synthetic materials developed which will be an improvement over the clays now used but there still are possibilities of better selection of clays and better methods of preparation, such as in the washing of the clay, the grinding and tempering of the mixture, etc.

I am of the opinion that increased tank life can be obtained by a means other than insulating. Figure 2*b* shows the insulation construction. We well know that there are glass currents washing down along the side of the wall, as shown in Fig. 2*a*. We can readily see that the glass at *A*, coming into

[1] See *Jour. Amer. Ceram. Soc.*, **8** [4], 191 (1925).

contact with the flux block at B will take part of the flux block into solution and become saturated. These currents may be due either to convection or to the fact that the saturated glass becomes heavier and passes down to the bottom of the tank, as shown at C. This tank-block-saturated glass, passing down along the side of the block, protects the lower portion of the block from further corrosion, and we soon have the block taking the form shown by the line at B or eventually D. As the flux block rapidly takes the shape shown by the line B in Fig. 2*a*, it would seem that this shape is one which promotes resistance to corrosion.

By giving the entire side wall an inclined face, or just the upper course in a deep tank, as shown in Fig. 2*c*, the glass A, coming into contact with the flux block at B becomes saturated for the given temperature, and is held *in situ*, which prevents further corrosion of the block by the glass. By giving the inclined face horizontal corrugations, we may still further

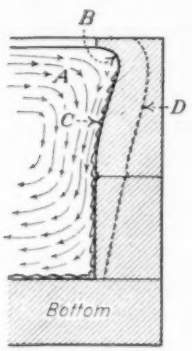

FIG. 2*a*.

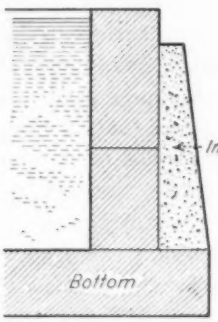

FIG. 2*b*.

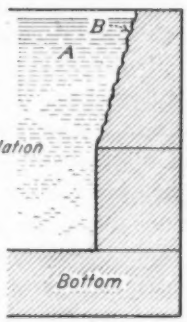

FIG. 2*c*.

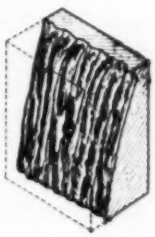

FIG. 3.

decrease the tendency of the saturated glass to pass down along the face of the block. The inclined face also gives greater thickness to the block in the bottom of the tank, which, as we have heard in connection with the discussion on insulation of tanks, is a decided advantage, in that it tends to increase the temperature of the glass in the bottom of the tank, giving greater melting volume.

Figure 3 shows the rough corrugated face ordinarily assumed by a tank block on corroding. The block in Fig. 2*b* has the advantage in that the inclined face is smooth and presents less surface in contact with the glass.

We believe this design has all the advantages of an insulated tank and has an added advantage, in that it holds the flux-block-saturated glass *in situ* and thereby prevents further corrosion, whether this corrosion be due to convection currents or to difference in specific gravity of the unsaturated and saturated glass.

G. V. MCCAULEY: The shelving action, on the side of the tank block

where there is a horizontal seam present, or on the underneath side of the throat of the cover block, seems to be due to factors other than those described, although those which have been described no doubt affect the solution of the block.

There are a series of holes that seem to have been drilled upward into the block, and run together on the sides. The more resistant the block is, the deeper will be these holes. I have seen them in blocks as deep as four inches, and no larger than your finger. They are not fissures to start with, because they are too round for fissures. In very resistant high alumina block I have seen them perfectly rounded. They cannot, therefore, have started from fissures. If the glass is broken out of these holes, you will almost invariably find in the top of each hole a pocket which does not seem to be filled with glass, but which might have been filled with vapor or gas. The erosive action seems to be a rapid one upward.

The erosion at the glass line is always very rapid compared with that at the side of the block. It seems as though we must attribute some of that to the motion of the glass, due to changes of surface in the glass by dissolving some of the block. This may be either a decrease or increase in surface tension. Either one will produce the motion and motion will always hasten erosion. There must be some of that surface tension effect in this drilling upward. If we wish to eliminate any chance of the gas getting under the block, then the sloping block Mr. Montgomery speaks of will do it. He has given an illustration and from my own experience I have constructed troughs where we flow glass from one tank to another and deliberately run the glass high enough to form a thin shelf over the top block. We get absolutely no cutting on the sidewalls, and the small amount of glass over the top will save the top of the block.

The smooth surface on the upper side of the horizontal shelf, then, is not to be considered as due entirely to droppings of products of solution forming this edge. If the glass merely rests on top of the block, it will form a layer of crystals varying in depth, depending on the temperature of the glass. These facts, I think, show that the drilling action which always takes place upward is accompanied by the presence of a gaseous atmosphere in the presence of which erosion is accelerated.

J. C. HOSTETTER: I am very glad indeed to have that point brought out. In Dr. Sosman's paper, dealing with fundamental principles, he spoke of mechanical conditions that would change the rate of reaction between the glass and the refractory. Surface tension was not mentioned.

I am quite sure from what I have seen so far, that there is merit in Mr. Brownlee's idea of insulating. When we insulate flux block on the outside, we can cut down the downward convection flow of the glass to a large extent, but I am still wondering about the surface tension action. When maintaining a constant level in the tank, there is a very violent cutting

right at the surface level, and in one extreme case, completely through in the working end. In this case it was not insulated in the true sense of the word. However, we did have a layer of fire brick on the outside of the flux block.

C. O. FAIRCHILD: The idea is that the glass contains dissolved gases which escape at an under surface. A trapped bubble of gases, such as water vapor and carbon dioxide, in equilibrium with glass at high temperatures, would produce a combination of great corrosive power. A retained bubble would dissolve its way upward.

G. V. MCCAULEY: On a block taken from a tank which has been in operation not long enough to wear the block out but long enough to score it, you will find the lower block in the tank probably nearly perfect, with a little round corner at its upper edge. This block may be eaten quite badly and the surface, instead of being smooth, will have the appearance of being full of little holes. The closer together these holes are, the smoother will the surface appear. If the block is very resistant, those holes may ultimately go up quite far, and get quite deep before they actually run together. In that case the appearance of the surface is something like the roof of a cave, with stalactites. The whole structure seems to be one of numerous nuclei of erosion, tending upward, and as they go upward, they spread out a little at the base and run together. As I say, the more resistant the clay, the deeper those holes ultimately become and the more pronounced they are.

I have seen the same action in a porcelain tube that had broken off and fallen into the tank and by some accident or freak of nature, the thing split lengthwise. When the tank was drained this tube was found split almost in the middle and lay on the bottom of the tank with its wall convex upward. At the upper edge, all along the length, about a quarter of an inch apart, were holes less than $^1/_{16}$ of an inch in diameter, just as drilled. This drilling was done by gas trapped underneath.

You get this drilling underneath a throat cover block. It is never smooth, but always has icicles hanging. If you will observe them closely you will find the hole-like formation. If you chance to find one that is full of glass, on knocking the glass out that there is a fairly round opening that gives the impression of never having had any glass in it, but full of gas or vapor.

S. R. SCHOLES: Would not the contraction of the glass leave an opening up in the upper end of those holes?

G. V. MCCAULEY: It is possible, but I think there is evidence enough to show that it is not necessarily so.

In case of clay blocks being used for a skimming action in feeder operation, our practice is to set these blocks about half an inch into the glass. They will very soon cut off at the glass line. If you catch them when they

are not quite cut off you will find these icicles very isolated. There may be just one-tenth of the original block structure left; the rest is cut off, but even above the glass level you will find these holes filled with glass. This gas cavity will be found just above the glass. There you would hardly expect enough vacuum in cooling the glass to produce that bubble.

C. E. FULTON: I have seen that same type of action on the under side of a floater. In fact, most of the floaters I have seen taken out have that structure.

R. F. GELLER: If what we are talking about is true, then we ought to build a tank with a cross-section like *A* where we would not get that action, but in this experimental tank would we not get a good test if we built a tank of a cross-section like *B* (Fig. 4)? Would we get a better test block in a laboratory if we built it as indicated and judged the relative merits of the block by the attack at *B*?

G. V. MCCAULEY: If you run the tank long enough you will get that without the trouble of making it that way.

R. F. GELLER: That is what we do not have time to do.

G. V. MCCAULEY: We have large bulb tanks. The refining end of them will run for perhaps six years without having to be repaired. They are only 24 inches deep and the blocks are continuous from the bottom to the glass line. We have to change those working-in blocks in time because the glass has actually dug into that seam between the bottom block and produced a cut so bad that there is not enough surface left to support the block. We have to take them out because they cut at the bottom instead of at the top. In there the temperature is only about 1200°C, and the action is slow.

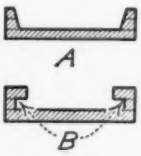

FIG. 4.

WM. BROWNLEE: I would suggest that that may be due to high pressure, together with the other circumstances.

J. C. HOSTETTER: Pressure due to the weight of the glass?

WM. BROWNLEE: Yes.

J. C. HOSTETTER: That is a factor, of course.

R. R. SHIVELY: Might these holes not be due to arsenic left in the batch?

G. V. MCCAULEY: Well, perhaps they are. I do not know how much arsenic is used. It may be that that does materially alter surface tension. It takes a very little amount of material in some instances to alter surface tension, enough to produce violent effects. As an illustration, stick a piece of camphor into a beaker of fresh water. If a few grains of dust are placed on the water surface, they will gradually creep up until they seem to just touch the camphor at the surface line. They then like a flash will go to the outside edge of the beaker. The whole surface of the water will be in violent motion, due to altered surface tension. If after five or ten minutes

you cannot measure any erosion on the camphor stick except at the water surface there will be a material cut, due entirely to the motion on the surface of the water.

When I first spoke of surface tension being altered I had in mind the alteration produced by the solution of the block itself. It may be altered either way to produce a motion.

J. C. HOSTETTER: I wish we had some real information on surface tension of glasses at various temperatures. The University of Illinois published some information on a limited series but the investigation was not carried far enough to give us the effects of impurities. I believe there is a great deal in the notion that erosion is due in part to changes in surface tension.

R. J. MONTGOMERY: There is one point I would like to bring out and that is the relation between the composition of the pot and the quality of the glass that is obtained. In using pots I am sure there is a direct connection and I imagine the same is true in glass tanks.

In Mr. Geller's study of the relative attack of glass upon various commercial tank blocks, he does not mention anything about the quality of the glass made in the experimental tanks or what effect the corrosion of the tank had upon the glass. Without doubt, alumina is harder to incorporate in the glass than silica and when we talk about high silica batches and high alumina batches we must take into consideration the rate of solution into the glass of the material corroded from the walls. This point should be stressed, as it is of more importance than most people realize. I do not believe that the full value of any experimental work may be obtained if the quality of glass is not taken into consideration.

J. C. HOSTETTER: Mr. Montgomery is making glass that cannot be sold unless it is optically perfect. I believe the rest of us in general are not making that. I gather from Mr. Geller's paper that the object there was to study corrosion on the block, and I should think that the more corrosive batch he could use the better, irrespective of the quality of the stuff that came out, as fundamentally he is interested in the results on the block.

R. J. MONTGOMERY: I think the subject of quality is coming more to the front all the time and I am not yet satisfied that my point is not well taken. We look forward to a time when we hope to obtain good quality glass from a tank. The plate glass industry is a large one and the quality requirement is high. We now get plate glass from tanks. Mirrors are made from plate glass and cordy glass cannot be silvered. I am sure the quality of the glass is important. Fundamentally we are making glass and not pots or tank blocks.

C. E. FULTON: In the plate and window glass industry the quality of glass produced with a given pot or tank block is of the greatest importance. Defects introduced by the pot or tank block such as stones or cords de-

crease the value of the product and if present in too great a quantity they will make the glass unsalable. It has been our experience that highly aluminous refractories cause stones and cords (or ream) to a very much greater extent than a highly siliceous pot or tank block. In our work the quality of the glass produced has been considered of greater importance than the life of the refractory.

R. F. GELLER: Mr. Montgomery has brought out an important point. There are variations in every trade, and for that reason we have limited our first work to that portion of the glass industry which, if my information is correct, has the largest production in the country, the glass bottle phase. Our work is limited to that phase, and what we are using at the present time is the commercial batch furnished by a bottle glass company. After listening to a glass man and all the troubles he has to turn out a good product, we have made no pretense of endeavoring to turn out nice glass. We are just making tests primarily of blocks, although the glass obtained is pretty fair.

F. C. FLINT: It is a long way from the glass Mr. Montgomery makes to that used for bottles. We cannot seem to attain the quality, not that we would not like to, but we just cannot get that quality and maintain production.

We melt the glass in tanks of considerable size, and are maintained from one week's end to the next, with considerable uniformity. We have three factors to consider. We want to get all the glass out that we can, up to the point where it ceases to be melted, evidenced by seeds. The block has little to do with that. It never affects that. The other is color. We have managed to maintain a good color, regardless of whether it has been in a tank with very good blocks or a tank of blocks that are so poor that the tank lasts not over five months. The only contribution that the block gives us, so far as poor quality is concerned, is to make cords that are so evident that they destroy the quality of the bottle. We always have cords to a small extent. We do not produce them by stirring up the glass. They are, however, present. When the cords get numerous enough to cause the breakage of the bottle, the tank block does not last very long.

DISCUSSION ON "THE MEASUREMENT OF EXPANSION OF FIRE BRICK AT VARIOUS TEMPERATURES"[1]

W. A. CARTER: In our construction of large boilers where we have the hollow wall construction, nine inches of hot wall and an air space, a good deal of care has to be exercised for expansion. It is a practice of our company to lay up the brick in horizontal courses, rubbing each course of

[1] F. A. Kohlmeyer, *Jour. Amer. Ceram. Soc.*, **8** [5], 313 (1925).

brick with a carborundum stone. We then put in a quarter inch corrugated paper every eighteen inches. Care should be exercised in using the paper where it will be reduced to ash. There have been cases where it did not burn out. These tests justified just what expansion to take care of.

S. S. COLE: In these tests, did you find hand-made or machine-made brick to be the most suitable?

F. A. KOHLMEYER: Our tests indicated that dry pressed machine made brick are the best for our use. The four brands selected for a further trial in service are manufactured in the Missouri district.

S. S. COLE: How is the fusion point of the ash obtained? Do you run them through the pot furnace or by the standard method for coal-ash?

F. A. KOHLMEYER: At present we are using West Virginia and Kentucky bituminous coals in both our stoker fired and pulverized coal burning furnaces. The ash of this coal has a fusion temperature of 2500°F or higher. Our coal-ash brick cone softening temperature tests were conducted in a gas-fired Surface Combustion Co. Volcanic Testing Furnace.

S. S. COLE: Do you have a small crucible inside?

F. A. KOHLMEYER: The cones made of composite samples of pulverized brick material and coal ashes were mounted on alundum cement pats and heated in a crucible in the furnace. The results could be observed by looking into the top of the furnace.

S. S. COLE: Was the operation under oxidizing conditions?

F. A. KOHLMEYER: This furnace was operated with oxidizing atmosphere.

S. S. COLE: In connection with the testing of brick under load and the measuring of the expansion of the same, Mr. Kohlmeyer spoke of the use of a transit. In some similar work with silica brick, we attempted the use of a transit but our results did not check. This might have been due to expansion of the furnace, because we used a slightly different method. Due to this error we are now using a cathetometer to measure the expansion of silica under load. This method gives us a very quickly obtained result, because we make a direct reading of the expansion upon the scale. The only difficulty we found with this method was the flame interference, but overcame this by use of an air blast upon the end of brick when making a reading.

As to the slagging test, where the coal ash penetration into a fire brick is measured, I believe that this test is not a satisfactory one or one exemplifying the service to which a brick is subjected by coal ash erosion. The best method, I believe, is where the coal ash is melted and runs down over the face of a set of brick, allowing the brick on being dissolved to flow off and new coal ash to take the place. Where a wall is on a slope, this action is what occurs in a boiler.

The ash ought to be the same as that in the coal being used and is a flue dust, collecting on the tubes of the boiler and on the arches. By the

use of an ash of this sort the same conditions as in a furnace are given the brick, and the brick on examination after testing will give a good idea as to what their service will be in a boiler.

D. W. Ross: In connection with some optical pyrometer readings, the exact length being hard to read due to the waves in the atmosphere, we found that in laying a small piece of the other brick, there would be a straight line across there and a line across the base. The surface would be slightly chilled for three or four seconds and it would appear that that line would show up so plain that there would be no change in temperature of the brick. They came out very clear and it was not at all difficult to get a reading.

F. A. Kohlmeyer: A holding tile is used in the construction of our pulverized fuel furnaces which is exposed to rather severe spalling conditions. This tile extends from the exterior to the interior face of the wall passing through the air space in the center of the hollow wall. Approximately 80% of the air required for combustion passes through the hollow wall thus cooling the refractory exposed to the fire and chilling the holding tile at a section near the center.

R. F. Geller: In the work we did which was reported last year, we worked some 42 bricks and as a result of the work, out of the 42 we picked out what we called the ten best, and they were based on the quenching. Several of those ten were dry pressed.

W. A. Carter: In the construction of our large boilers in which we have hollow walls, there being 9 inches of hot wall, a 12-inch air space and 9 inches in the outer or cold wall, a great deal of care has to be exercised in providing for the expansion of the brick in the hot wall. It is our practice to lay the brick in horizontal courses, rubbing down each course with a carborundum rubbing stone so as to provide a thin joint. In each horizontal course there is inserted every 18 inches, or thereabouts, a $\frac{1}{4}$-inch corrugated paper, which burns out and leaves space to provide amply for the expansion of the brick. Care should be exercised in selecting a paper that will burn to a small amount of fragile ash. There have been cases where unsuitable paper has been used, that is, paper that did not burn out properly. In these cases the brick were not free to expand the required amount without wrecking the setting.

H. W. Brooks: In our consideration of slagging problems of boiler furnaces we are often inclined to concentrate attention on only one of the four major slagging problems, namely, slag erosion. With Eastern bituminous coals containing ashes of high fusion temperatures the principal slagging difficulty does not originate from erosion but from adhesion. This results in rapid destruction of the furnace walls in the removal of the built-out slag through the impact of firemen's tools, and is the principal cause of refractory maintenance in furnaces using these coals.

In the central district of the United States, however, where there are bituminous coals containing ashes of medium low temperature fusion points there are three other principal slagging problems which in the order of their importance are as follows: (1) slag erosion on furnace walls; (2) slag formations within the fuel bed itself; (3) slag formations on and between the first and second rows of boiler tubes which eventually plug up the furnace so that the necessary drafts will no longer pass for the desired boiler ratings.

With regard to the first problem, erosion, it is probable that the ash-brick cone test gives some measure of two of the four factors which must be considered in its analysis. These four factors are: (*a*) slag viscosity at furnace temperature; (*b*) viscosity of bond clay in refractory at furnace temperature; (*c*) porosity of refractory at furnace temperature; (*d*) mechanical strength of refractory at furnace temperature. The softening and flow intervals of an ash-brick cone considered in conjunction with the cone softening temperature probably will give a direct measure of the first two of these factors. This data, however, tells us nothing of the porosity of the refractory nor of its mechanical strength at furnace temperatures. Both of these factors must be considered in an analysis of slag erosion. The ability of the slag to penetrate and commence to decompose a refractory is obviously a direct function of the refractory porosity. Mechanical strength of a refractory must be considered for oftentimes small pieces of the refractory are washed down by the slag and an examination of the slags of boiler furnaces using Middle Western coals often shows these small pieces washed down with apparently but little slag absorption.

Refractory porosities and mechanical strengths at furnace temperatures are easily determinable with tests at present formulated by the A.S.T.M. It seems, therefore, well within the range of possibility for those interested in refractory research to devise a formula for slag erosion to include the four factors mentioned above from which formula a refractory brick buyer, after running the ash brick cone test at furnace temperatures, could predict what service he might expect with a given refractory, a given coal and a given furnace.

In regard to the problems two and three, of slag formations within the fuel bed and on the boiler tubes, these are purely functions of the coal ash itself, and hence are not matters of particular interest to refractory engineers.

F. A. HARVEY: The manufacturer can do nothing else than welcome all of the tests which the consumer makes and the more he can obtain concerning his own uses the greater chances the manufacturer has of supplying him the refractory; but there is something which is more vital to the manufacturer on first sight than it is to the consumer.

If the consumer decided on some test, such as the spalling test, which he is going to take as a criterion to discard a large number of refractories, he avoids all danger of getting a refractory into his setting which will cause him trouble, but he also runs the chance of excluding the number that would have an opportunity of going in.

I had an occasion about six months ago to visit a company who were making tests on refractories and the criterion they used was the fusion point. They were very frank in allowing the manufacturer access to their results and among other brick which were rejected on the basis of fusion point, there was one which has a national reputation for success yet, on the basis of lower fusion temperature, this brick was excluded. It was in my mind unfair to that manufacturer. There is a chance in this case that this spalling test is excluding certain refractories that would give you satisfactory service. This is the point that you must consider.

R. F. FERGUSON: Mr. Kohlmeyer, you have not told us what you expect to find. Have you specifications?

F. A. KOHLMEYER: We have drawn up specifications for fire brick, but consider them as tentative and subject to revision.

L. C. HEWITT: We note the spalling factor was given prime importance in making tests and I have been trying to determine in my own mind just how important spalling is in large powdered fuel settings. It is, of course, of prime importance that the ceramic engineer, when devising mixes and processes of manufacture for producing materials, have thoroughly in mind just what these conditions are, as well as the relative importance of the various destructive factors that influence the life of the brickwork.

I have been led to believe from my own observations that the tendency to spall in a powdered fuel furnace is not as great as it is in some stoker-fired types of furnaces, for the service factors affecting the life of the bonding tile are, of course, somewhat different from the type of brick themselves, due to the strains which these tile must withstand in holding the wall rigid, and would accordingly welcome any discussion relative to the importance of the various factors that should be taken into consideration in adapting refractories for powdered fuel service.

D. W. ROSS: In connection with some thermal expansion measurements which we made at the Pittsburgh branch of the United States Bureau of Standards in 1916, on silica brick at high temperatures, we found it very difficult to make exact readings of marks on test specimens exposed in an open fire, at temperatures in the neighborhood of 1350°C.

We found, however, that if the ends of the test pieces be ground plane, so that the traces of the ends are straight lines, and that other plane refractory surfaces be brought into contact with these ends, and the whole heated to any desired temperature in an open fire, and the fire be then momentarily shut off, that the lines of contact between the ends of the test

specimen and the adjoining pieces are plainly visible. This is because of a slight chilling of the surface of the test piece, whereas the interior as shown at the contacts, remained at the higher temperature.

With standard 9-inch silica brick, such as we used, it was possible to make cathetometer readings of these contacts and get the fire going again in a very few seconds, so that the specimen probably changed in size very little, while the readings were being made.

DISCUSSION ON "SOME FORMS OF SULPHURING ON EARTHENWARE GLAZES"[1]

K. M. SMITH: Can you get sulphuring from natural gas?

T. A. SHEGOG: I have never seen it. I do not think it contains any sulphur. Natural gas and wood are about the only fuels I think in common use that do not contain sulphur.

K. M. SMITH: You used only coal and oil?

T. A. SHEGOG: Yes.

K. M. SMITH: How did you determine the sulphuric acid? Did you titrate?

T. A. SHEGOG: I precipitated with borium chloride and weighed.

A. V. BLEININGER: I think Mr. Shegog has covered the thing pretty completely and it would be very difficult to add anything to it. There are all kinds of variations of the same difficulty and some times they are extremely hard to distinguish.

We had a case which might have been mistaken for sulphate effect but which was due only to a very high velocity of gases flowing around the saggers. The problem always is whether or not we are dealing with sulphuring and that is not quite so simple. Mr. Shegog brings this point out.

It is not the easiest thing to differentiate between sulphuring and the effect which is brought about by so-called airing, where we have too high velocities of kiln gases.

H. GOODWIN: I should like to speak with reference to sulphur from natural gas. Perhaps some members will recall this question was raised, if I remember correctly, at the St. Louis Meeting in 1907 on a paper by Herford Hope on his experience at the Wylie China Company, Huntington, W. Va. It was found that we could get sulphuring from natural gas.

K. M. SMITH: That raises another question. Will the sulphuring help crystallize zinc out of a high zinc glaze?

T. A. SHEGOG: Just what do you mean by a high zinc glaze?

K. M. SMITH: About .245 equivalent. We developed crystals quite

[1] Published, T. A. Shegog, *Jour. Amer. Ceram. Soc.*, **8** [3], 148 (1925).

frequently in this high zinc glaze. They are very similar to those speckled spots on the ware you passed around. Would the little sulphur that could communicate either through the water or natural gas help centralize those crystals and start crystallizing?

T. A. SHEGOG: The glaze on those pieces contains less than 3% dry weight of zinc. I have had no experience with very high zinc content.

E. SCHRAMM: Several years ago I carried out some experiments in an electric tube furnace in an effort to produce at will a typical sulphur scum and to determine the conditions of its formation. Since on burning coal nearly all the sulphur appears in the gases as dioxide it seemed likely that we must look to the dioxide rather than the trioxide as the source of sulphuring. Accordingly, I passed pure sulphur dioxide both dry and wet, mixed with varying proportions of air, over pieces of dipped ware at various periods of the glost fire. Scum was produced with either wet or dry sulphur dioxide only at the upper end of the glost burn.

The "polka dot" scum recalls some freak pieces of ware from a glost kiln which were impregnated with carbon apparently carried down from the kiln gases and trapped by the melting glaze before it could burn out completely. The surface appearance of this ware was not unlike the "polka dot" scum referred to in the paper.

C. E. DOLL, SR.: It might be interesting to note our experiences in tunnel kiln operations as bearing out some of the data that was read in this paper.

In firing a glost Harrop tunnel kiln we found, even using fuel oil wherein we had a specification of less than one-half of one per cent sulphur, that we were getting what is commonly known among the old school of potters as airing. In years gone by we used to think it had to do with airing. Experiments showed it was due to sulphuric acid deposits upon the ware during the early stages of the development of the glaze, and in order to demonstrate and prove this conclusively we made openings in the crown of our tunnel kiln.

We could take pieces of ware to which glaze had been applied and place these pieces of ware even inside, but not tightly wadded, let them go through the entire preheating zone of the tunnel kiln and they would come out with the glaze dulled by this deposit. We could go further along the kiln to where the kiln was beginning to show red, possibly at 1000° or 1200° and through an opening in the crown drop a piece of glazed ware and let that piece of ware travel through on top absolutely exposed. It would come out perfectly bright, showing that the attack in the deposit upon the ware occurred in the early stages of the glaze development and was affecting the ware at that time.

This proposition is such a problem that in designing the new kiln which we are about to erect we plan to use a muffle. While it will be a direct

fired kiln, yet in the preheating zone during which the ware is being brought up to 1000° or 1200°F, we intend to muffle that section so as to take out the gases and prevent this deposit from occurring.

DISCUSSION ON "COMPARISON OF ENGLISH VS. AMERICAN PYROMETRIC CONES"[1,2]

S. S. COLE: The Bureau of Standards conducted their investigation on cones in a muffle furnace so as to have uniform temperature control. The comparison was made to a point at which the English cone touched down. We found quite a number of variations in that respect and tests on all cones were run two or three times to check our results.

R. F. GELLER: We only went up to cone 20, but in the range that we both covered it seems to check up very well. Mr. Cole, did you notice any bloating?

S. S. COLE: Bloating occurred at cones 14–16. It looked like boiling or bubbles.

R. F. GELLER: While I do not have the charts with me and cannot make a definite comparison, it appears that the results which you obtained at Mellon Institute and those obtained at the Bureau, check as well as could be expected. In our work we noted bloating of the English cones in the range from cone 10 to cone 15, inclusive. Cone 19 also showed indications of bloating.

S. S. COLE: The temperatures given in the tables were obtained about 10 months ago from the Bureau.

R. F. GELLER: Since the Bureau is at this time investigating as accurately as possible the relation between cone composition, softening point and time of heating, it is believed advisable not to refer to softening points obtained at the Bureau until this investigation has been completed. It is hoped that the results obtained will be conclusive.

S. S. COLE: It would be of interest to the users of cones if we could publish the temperatures of cones produced by the English.

R. F. GELLER: It would, no doubt, be interesting to publish the softening points of the English cones as determined in England if we could state definitely how they were determined. Without that information, however, the data would be valueless and would only add to the contradictory temperatures already in the literature.

C. E. BALES: Last year at the Atlantic City meeting, Dr. Orton pre-

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[1] See *Jour. Amer. Ceram. Soc.*, **8** [7], 462 (1925).

[2] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Columbus, Ohio, Feb., 1925.

sented some data on cones to the Committee on Standards. Photographs were exhibited showing English, French, German and American cones and there was considerable variation. I think that if Mr. Cole had investigated German cones he would have found that they too vary considerably from American cones. Several years ago we used some No. 9 German cones in kiln firing, but when their cones were over, the No. 7 American cones would still be erect. We now use the Orton cone exclusively. The German Naval Specifications call for a fusion point of cone 34. In America brick softening at cone 32–33 are good brick and this makes me believe that our cone 33 is possibly equivalent to the German cone 34.

F. A. HARVEY: One of the biggest difficulties that refractory manufacturers have is trying to tie these cones up with temperatures. We get specifications right along in temperatures. The cones do not measure temperatures. They are a measurement of quantity of heat, and without any disparagement of the work of the Bureau in their experiments to determine the temperature relations, we want to get out of everyone's minds the idea that the cone measures temperature.

R. F. GELLER: We are not trying to tie up cones with temperatures. We are trying to tie up temperature and composition. We all know that when you get up in that range of 1500° or 1600° that the optical pyrometer is not correct.

A. F. GORTON: If we consider an actual case, for instance, in a very large kiln with a great tonnage where there is a vast reservoir of heat, the cone measurement of time, temperature, treatment or maturing as we speak of it, is a measure of the viscosity development. Viscosity or state of fluidity is a matter of time at temperatures above the softening temperatures of the more fusible minerals present. The melting point of a mineral crystal is definite but the melting point of a mixture of minerals is not very definite.

What is the softening point of glass? The only test is to subject the glass to a definite stress or load at a fixed temperature and note the rate of deformation.

To think of the cone as a measurement of temperature is no more scientific than measuring the deformation temperature of a cone or rod under a definite stress by putting it into a hot furnace at a fixed temperature and then measure it at the rate of deformation.

In large kilns the heating is so slow that when the cone goes down it is not actuated by the temperature but by the amount of materials in the cone that is sufficiently fused. Deformation, under definite stress, should tie up more nearly with the actual temperature.

F. A. HARVEY: I think that we can safely leave the question of relation to temperature of cones to the work which the Bureau is doing and which undoubtedly will clear up this subject. To Dr. Gorton, may I say

that after several years of experience in firing silica and clay refractories the measure of temperature is not what the cones show.

R. F. FERGUSON: Dr. Gorton's remarks are out of line with what we are trying to do.

A. F. GORTON: I want to point out that when you consider 70 or 100 tons of ware in a kiln, and you consider the mass of the cone, it seems to me that you will have to admit that you are measuring what the glass works tried to measure in regard to glass, and that you are rating the deformation with rather a small stress on an object that has a very small mass.

ACTIVITIES OF THE SOCIETY

NEW MEMBERS RECEIVED FROM SEPTEMBER 15 TO OCTOBER 15

PERSONAL

Francis E. Allen, 322 Sixth St., Ames, Iowa. Student.

Edward L. Bohn, 123 Saranac Ave., Buffalo, N. Y. Sales Representative, Dover Fire Brick Co.

Hewitt O. Fearn, 5248—17th St., N. E., Seattle, Wash. Ceramic Fellow, University of Washington.

Robert B. Hand, Y. M. C. A., Elyria, Ohio. Chief Chemist, The Pfaudler Co.

Fred E. Hilburn, Salina Inn, Salina, Westmoreland Co., Pa. Kier Fire Brick Co.

Everett O. McFadon, Karr Range Co., Belleville, Ill. Superintendent of Enamel Department.

Henry Marley, Salina Inn, Salina, Westmoreland Co., Pa. Kier Fire Brick Co.

Himansu Kumar Mitra, 221 Atwood St., Pittsburgh, Pa. Graduate Student.

Remington M. Murphy, 35 E. Pultney St., Corning, N. Y. Ceramic Engineer, Corning Terra Cotta Co.

Ralph J. Paddock, 2011 Chelsea Road, Columbus, Ohio. Fellowship with the U. S. Bureau of Mines.

Layton C. Pinckney, 1927 Waldeck Ave., Columbus, Ohio. Student.

Marie Regnier, 134 Sidney St., St. Louis, Mo. Secretary and Treasurer of the Silica Enamel Sign Co.

Paul John Slegel, 407 Welch Ave., Ames, Iowa. Student.

Fred W. Sontum, R. D. No. 2, New Castle, Pa. Superintendent of Shenango Pottery Co.

CORPORATION

Porous Products Corporation, Baltimore, Md., Frederick E. Kern, Vice-President.

Membership Workers' Record

	Personal	Corporation
Paul E. Cox	1	
Dover Fire Brick Co.	1	
E. A. Eigenbrot	2	
M. C. Gregory	1	
H. C. Harrison	1	
M. R. Hornung	1	
S. M. Kier	2	
W. A. King	1	
D. A. Moulton	1	
A. Silverman	1	
Hewitt Wilson	1	
Office	1	1
Total 15	14	1

PERSONAL NOTES OF MEMBERS

Robert J. Anderson, Consulting Metallurgical Engineer, of Pittsburgh, Pa., has requested that communications be addressed to 1658 Woodward Ave., Lakewood, Cleveland, Ohio.

M. L. Bell has been transferred from the Altoona, Pa. branch of the General Refractories Co. to Baltimore, Md.

Marion W. Blair, formerly of St. Louis, Mo., is living at 2131 S. Center St., Terra Haute, Ind.

E. A. Brockman, who is associated with the Roessler and Hasslacher Chemical Co. of Chicago, has requested that his address be changed to 526 E. 4th St., Lincoln Apartments, No. 18, Cincinnati, Ohio.

O. I. Chormann has moved from Niagara Falls, N. Y., to Rochester, N. Y. He is associated with the Pfaudler Co.

Roland J. Clark of Olean, N. Y., is located at the College of Mines, University of Washington, Seattle, Wash.

G. M. Grady, member of Class of 1925, Ceramics at Ohio State University, is located with the Northwestern Terra Cotta Co., Chicago, Ill.

R. B. Ladoo, formerly with the Southern Minerals Corp., Cleveland, Tenn., is now associated with the Colorado Fluorspar Corp., Cowdrey, Colo.

Garland Lufkin has been appointed to succeed L. H. Maxfield as corporation representative of the Illinois Glass Co., Alton, Ill.

Paul S. MacMichael of Auburn, Wash., requests that his mailing address be changed to 1190 Dexter Horton Bldg., Seattle, Wash.

D. M. McCann sends as his address University Club, Akron, Ohio.

Max Y. Seaton of the Sierra Magnesite Co., Porterville, Calif., is spending six months at Chula Vista, Calif., with the California Chemical Corp. Mr. Seaton will return to Porterville later.

Joe F. Straumford has moved from Portland, Oregon, to 1206 S. Ford St., Los Angeles, Calif.

Gail R. Truman has moved from Glendale, Calif., to Brazil, Ind.

W. W. Tsou, who has been attending Alfred University, has entered the graduate school in ceramics of the University of Illinois.

W. R. Wyckoff is affiliated with the Department of Ceramics, Rutgers College, New Brunswick, N. J.

BALTIMORE-WASHINGTON SECTION MEETING[1]

The first meeting of the Baltimore-Washington Section of the AMERICAN CERAMIC SOCIETY for the 1925–26 season was held at the Old Colony Club, Emerson Hotel, Baltimore, Md., at 7:00 P.M., October 3, 1925.

The meeting was opened with a fine chicken dinner, to which each of the twenty-four members present offered to do justice. The program opened with a paper by W. N. Harrison of the Bureau of Standards on the "Physico Chemical Factors of Enamel Suspensions." The object of this work is to study the factors affecting properties of enamel slips in order to control their working properties. The investigation has been carried on under two methods. The first to study in a fundamental way the mechanism of known changes in properties, such as the marked change in consistency which takes place when the electrolyte is added. The second is to vary the kinds and amounts of constituents and the length of time of the various treatments, and note the effect upon the properties. The paper brought forth considerable comment from Mr. Sweely, who suggested many new lines of thought which might well be used in the future work.

The second paper was by R. A. Heindl of the Bureau of Standards, entitled "A Progress Report on Sagger Investigation." Mr. Heindl told of the enormous amount

[1] D. H. Fuller, Secy.

of work which had been done on this problem, and gave a clean insight into the varied physical properties of fifty-one different sagger clays now in use in this country. From these results it is easy to see that there is room for much research work along this line. The paper is now in the hands of the Editorial Committee of the Bureau of Standards and will soon be printed in full detail in the *Journal of the Society*.

The program closed with a talk by B. T. Sweely of the Baltimore Enamel and Novelty Co. on practical testing of the pickling solutions. Mr. Sweely gave a method of testing pickling solutions for plant use which requires only a short amount of time and very little labor. After the standard acid solution is made up for pickling purposes it invariably becomes weaker as metal is introduced to be cleaned, and this causes the addition of more acids at various intervals. Therefore some method must be devised by which the strength of the solution may be determined quickly at all times. Mr. Sweely's test consists of testing a small quantity of solution with methyl orange, and if the solution is weak more acid is added.

Karl Turk suggested that hereafter all temperature readings be transferred to the Fahrenheit scale as the practical man is more familiar with this than with the Centigrade scale.

The next meeting of this Section will be held in Washington, December 5, 1925.

LUNCHEON GIVEN BY PACIFIC NORTHWEST SECTION

A luncheon was held on September 25, 1925, in honor of H. G. Schurecht, U. S. Bureau of Standards and National Terra Cotta Society at Seattle, Wash.

Twenty-four members of the Pacific Northwest Local Section met with Mr. Schurecht in the L. C. Smith Building restaurant, Seattle, Washington, for discussion of terra cotta problems. The informal meeting was continued for over three hours, so interesting and valuable were Mr. Schurecht's observations of terra cotta in the wall and experiments in the Bureau of Standards laboratory.

Those present: Hewitt Wilson, Hewitt Fearn, R. Bowman, H. R. Goodrich, Roland Clark, T. E. Nicholson, Donald P. Graham of the University of Washington, C. E. Williams, of the Bureau of Mines, P. S. MacMichael, A. L. Bennett, W. E. Clark, Sam Kinghorn, of the Gladding, McBean and Co. (Northern Clay Co.), Frank and Arthur Houlahan, A. Thompson of the Builders Brick Co., F. A. Carson, Sam Geijsbeek and H. B. McMillen of the Denny Renton Clay and Coal Co., John Stirrat of the Seattle Brick and Tile Co., George McFarlane, of the Seattle Brick and Tile Co., W. J. Howard, P. N. W. Brick Manufacturers Association, D. Thomason, Clayburn Co., Ltd., Clayburn, British Columbia, Albert Armstrong, Dennison Interlocking Tile Corp.

MINUTES OF THE MEETING OF THE JOINT COMMITTEE ON FOUNDRY REFRACTORIES

This meeting was called to order by L. C. Hewitt, Chairman on Coöperation, AMERICAN CERAMIC SOCIETY, at Mellon Institute, Pittsburgh, Pa., 10:30 A.M., September 14, 1925.

Those present were: L. C. Hewitt; M. C. Booze, Senior Fellow, American Refractories Institute; C. E. Bales, Louisville Fire Brick Company; C. N. Ring, Chairman, Refractory Committee, American Foundrymen's Association, Electric Steel Founders' Research Group; Jas. T. MacKenzie, American Cast Iron Pipe Co., Birmingham, Ala.; Mr. Colwell, Division of Simplified Practice, Department of Commerce; Mr.

Corbett, Steel Founders' Society of America; J. L. Cummings, Secretary, Refractory Committee, American Foundrymen's Association.

Letters received from R. F. Geller of the Bureau of Standards and Mr. Morehead of the American Malleable Castings Association were read, expressing their regret at being unable to attend and best wishes for a successful meeting.

Mr. Hewitt explained the formation of the Joint Committee on Foundry Refractories, its aim to standardize on specifications as to sizes, simplification and testing of foundry refractories, for the American Foundrymen's Association including each of the branches of the industry, such as the gray iron, malleable, steel and non-ferrous.

Mr. Hewitt then explained the history of the movement and the results of the Columbus Meeting of the AMERICAN CERAMIC SOCIETY and their agreement to sponsor the movement to standardize on foundry refractories, with the Refractory Committee of the American Foundrymen's Association, and that the meeting now in session was the result of the Columbus Meeting.

As Temporary Chairman of the Committee on Coöperation of the AMERICAN CERAMIC SOCIETY, Mr. Hewitt made the following appointments of this committee to consist of: American Foundrymen's Association (C. N. Ring, R. E. Kennedy, J. L. Cummings); Steel Founders' Society of America (Mr. Colbert); Bureau of Standards (R. F. Geller); American Refractories Institute (M. C. Booze, J. S. McDowell); Bureau of Mines (G. A. Bole); Division of Simplified Practice (Mr. Colwell); American Malleable Castings Association (Mr. Morehead); American Society for Testing Materials (F. A. Harvey); Electric Steel Founders' Research Group (C. N. Ring); Institute of Metals Division of A. I. M. E. (Not yet appointed); AMERICAN CERAMIC SOCIETY (L. C. Hewitt, C. E. Bales); American Electrochemical Society (J. T. MacKenzie).

The election of officers for the Joint Committee was then taken up, the chairmanship going to L. C. Hewitt, upon motion of Mr. Ring, which was duly seconded and carried. Mr. Ring then entered a motion to elect J. L. Cummings Secretary, which was duly seconded and Mr. Cummings, Secretary of The Refractory Committee of the American Foundrymen's Assn., was elected Secretary of the Joint Committee.

Mr. Hewitt then called upon Mr. Ring, Chairman of the Refractory Committee of the American Foundrymen's Assn., for suggestions as to a program to be followed by the Joint Committee. Mr. Ring suggested that committees be formed as follows: Committee on Review of Literature, Committee of Standardization and Simplifications, Committee of Testing and Specifications, and a Committee on a Survey of Conditions of the Branches of the Industry—each of these committees to consist of a maximum of five members and that the Chairman of these committees should be a member of the Joint Committee, and that the Chairman of the various committees name the balance to fill this committee. Whenever possible, each of these committees to contain a technical man, a man from the producers, and a consumer of foundry refractories, which met with the approval of the Joint Committee.

Discussion then followed on the various programs relative to the reason for the failure of foundry refractories, this discussion being led by M. C. Booze. Mr. Booze explained the procedure employed by the A.S.T.M., and the work done to date, covering the principal reasons why refractories fail.

Although tentative, Mr. Booze believes the American Refractories Institute would coöperate with the Joint Committee on Foundry Refractories to secure the proper results of reports, tests, etc. This was tentative due to the fact that the American Refractory Institute had not held their meeting.

The next step resulted in a discussion of a tentative program for the Joint Committee to proceed upon and Mr. Booze suggested that we must have an outline of the work that can be accomplished for the foundry industry, and under what conditions

refractories are used by the foundry industry, what tests would be most practical and a study of failures and of service conditions. This study, with reports, as well as of review of literature on the subject would lead to recommendations being made.

A survey of the various lines of the foundry industry was next discussed together with necessary expense thereto and the American Foundrymen's Association raising the money for the work. Mr. Ring, Chairman of the Refractory Committee of the A.F.A., stated that the proper procedure would be to appoint committees, have them functioning first, gathering all information available, and that with such a program of procedure that the matter of raising sufficient funds for the survey of the foundry industry could be taken up with C. E. Hoyt, Secretary of the American Foundrymen's Association and its officers, and with this program properly outlined could ask the A.F.A. to raise the funds to promote the work of the survey. Mr. Cummings, Secretary of the Refractory Committee of the A.F.A., concurred with Mr. Ring on this procedure.

The next step discussed was the best methods to obtain information for the Joint Committee on Foundry Refractories whether by type of furnace, such as malleable, cupola or open hearth, or by branches of the industry, such as malleable, gray iron, steel, etc. This discussion was led by Mr. Colbert and it was decided to operate by branches of the industry.

Mr. Bole, of the Bureau of Mines, stated that the Bureau had been conducting an investigation relative to refractories for open hearth practice and such information would be available to the Joint committee.

Mr. Colwell, Department of Simplified Practice, Department of Commerce, stated that at the former meetings with the American Foundrymen's Association Refractory Committee, on the work on standardization of the size of sleeves and nozzles, very little progress had been made and that the Bureau would be glad to assist in the work.

The following appointments were then made by Chairman Hewitt on sub-committees:

The Committee on Review of Literature, Mr. Kennedy, appointed with power to select the balance of the members to compose this committee.

The Committee on Standardization and Simplification, Mr. Corbett, of the Steel Founders' Society of America, was appointed Chairman to be assisted by Mr. Colwell of the Department of Simplified Practice of the Department of Commerce with power to name the balance of the committee.

The Committee of Testing and Specifications, M. C. Booze, Chairman.

The Committee on Survey and Conditions of the Branches of the Industry, C. N. Ring, Chairman of the A.F.A. Refractory Committee appointed Chairman.

Various discussions as to refractories used in foundry industry and the standardization of same followed and it was decided best to get the various committees functioning and Mr. Hewitt suggested that names of various men who might be available to serve on the sub-committees and who would be named tentatively for this work.

On the Committee of Survey of Conditions of the Branches of Industry, E. H. Van Schoick, of the Chicago Retort and Fire Brick Co., Jas. Allen, of The International Harvester Co., Mr. MacKenzie and, for the Non-Ferrous section, H. M. St. Johns, of the Detroit Lubricator Company.

On the Committee of Testing and Specifications: R. F. Geller, J. Spotts McDowell, of the Harbison-Walker Company, of Pittsburgh, Pa., Mr. Valentine, of the General Electric Co., of Erie, Pa., and C. E. Bales, of the AMERICAN CERAMIC SOCIETY.

On Committees of Standardization and Simplification: Roy Wetherill, of the Department of Commerce, Utilization of Metals Division.

It was then recommended by Mr. Booze that a member of his Committee of Testing and Specifications, of which he is Chairman, be from the American Refractories

Institute and a suggestion was entertained naming J. M. McKinley, of the Crescent Refractories Co., of Curwensville, Pa., serving on this committee.

Jas. T. MacKenzie was present at this meeting by invitation. Not being a member of the Joint Committee, it was suggested by J. L. Cummings, the Secretary, that an invitation be extended to him by C. E. Hoyt to become a member of the American Foundrymen's Association, Refractory Committee.

After discussion as to procedure and appointments by Chairman of the sub-committees to start same functioning, the meeting was adjourned with invitation to those present to visit the A.F.A. Meeting at Syracuse and take part in a round table discussion, which would be held Tuesday, October 6, in the Dairymen's Bldg., Syracuse State Fair Grounds.

OBITUARY

Samuel A. Weller

Samuel A. Weller, pioneer pottery manufacturer and owner of the Weller potteries, died in Washington, D. C., October 4, 1925, at the age of seventy-four years. Mr. Weller had not had rugged health for several years and he suffered a stroke of paralysis while in Washington which was the immediate cause of his death.

Mr. Weller was born in the little town of Fultonham, Ohio, near Zanesville, and when a young man hardly out of his teens he established a small pottery for the manufacture of flower pots. The accompanying pen sketch[1] will illustrate the primitive cabin built of unhewn logs, his first pottery and the old horse, used to turn the grinding wheel which broke up the clay, going around a muddy circular track pulling a twenty-foot boom attached to the mill. This horse also hauled the crude clay from the clay beds to the factory and after the ware was made the horse was used to haul the ware to the railroad for shipment to the trade. Mr. Weller, himself, not only took active part in the physical processes of manufacture but also traveled around the country selling his ware.

In 1882 he established a warehouse in Zanesville and six years later he moved his factory to the Muskingum River bank. Mr. Weller erected a new plant in 1892 and started the manufacture of jardinieres, hanging baskets, umbrella stands and other articles of pottery and was forced to enlarge his plant again in 1893 and 1894. Almost the entire plant was destroyed by fire in 1895 but Mr. Weller immediately rebuilt and

[1] From an article framed in Mr. Weller's office, 1906.

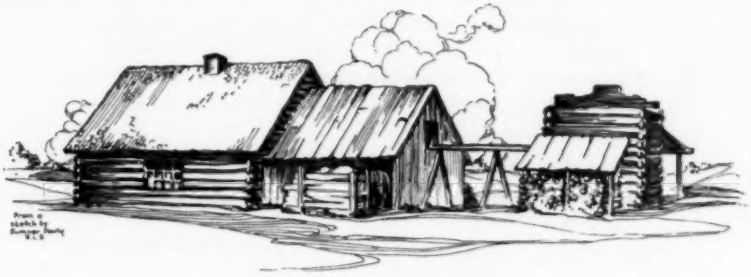
The illustration here shown is from a drawing made by Sumner Fauly, who was employed in the factory, if it can be dignified by such a name in 1872, and who has been continuously with Mr. Weller ever since.

From this small beginning Mr. Weller's pottery has grown till he now has a factory covering acres in extent, fitted up in the most modern way. From one kiln, crude and inconvenient, he has increased to thirty-five kilns. The improvement in his wares has kept pace with the works until today he has an enviable reputation as a maker of artistic ware.

Through the open door may be seen the hindermost parts of a horse. This horse was old and scrawny, his coat was rough, he was thin and altogether a disreputable-looking beast, but he was worth a lot to Mr. Weller, for besides furnishing the power to grind the clay he served as means of communication with Zanesville which was ten miles away. It is said that Mr. Weller owned a vehicle about as antiquated as the horse, and that when he went into town young Fauly would go with him. Before reaching the more fashionable part of Zanesville, Mr. Weller usually discovered that he had an errand on the outskirts, and would request his "private secretary" to drive to the livery stable. He would then take a horse car for the rest of his journey.

SAMUEL A. WELLER

enlarged the plant. He purchased the Lonhuda Pottery Company of Steubenville, Ohio, in 1896. This pottery established in 1892 was making art pottery with decorations hand-painted under the glaze in Rookwood style. The production of the "Lonhuda" ware was continued and with the addition of the "Louwelsa" and "Sicardo" the ware attained an international reputation. A few years ago, because of his increasing business, Mr. Weller purchased the Sharon Avenue plant of the old American Encaustic Tiling Company and later he added the Zanesville Art Pottery plant to his other plants. Other lines were added and it was not long before the Weller business became one of the leading industries of Zanesville, which position it has held up to the present day.



Weller's old factory

Throughout his fifty-three years in the pottery industry Mr. Weller was the dominating figure in his business. He continued his pottery as an individual business until three years ago when he incorporated the concern. Mr. Weller did not relax his active participation in the work, however, until his death.

Mr. Weller is survived by his wife and two married daughters. A son-in-law, Frederick J. Grant, is treasurer of the Weller Company. Two nephews were also associated with him, Harry Weller, in charge of the manufacturing and Frank Weller, who was personal assistant to Mr. Weller.

NOTES AND NEWS

MEETING OF THE OHIO CERAMIC INDUSTRIES ASSOCIATION

Lord Hall, O. S. U., November 20-21

The second meeting of the Ohio Ceramic Industries Association will be held on Friday and Saturday, November 20 and 21, in Lord Hall, O. S. U., Columbus, Ohio.

The committees of this Association concentrated the past year on establishing a secondary school in ceramics at East Liverpool, the first of its kind. The school started this fall with scheduled classes and equipped laboratories, as a part of high school of that city. Mr. Heusch, director of the State Vocational Board, and the Committee on Education of this Association have started negotiations for a similar school in Zanesville and are planning to extend this scheme of secondary ceramic schools to other ceramic centers in Ohio.

Prof. A. S. Watts, of the Ceramic Department at Ohio State University, is planning a program of University Extension in ceramic education.

Other points of vital interest to ceramic manufacturers are to be discussed in addition to an excellent program of papers.

A block of seats for the Ohio State-Illinois football game has been reserved for the benefit of those attending the meeting.

ACTIVITIES OF THE CZECHOSLOVAKIAN CERAMIC SOCIETY

By Rudolf Barta[1]

Czechoslovakia abounds in ceramic raw materials and is fast becoming the center of ceramic science in Europe. The Czechoslovakian Ceramic Society has about 120 members. These members come from Czechoslovakia, Denmark, France, Germany, Jugoslavia and Poland.

The Society is located in Prague and meetings are held in various cities three times a year. The organization has the following Divisions and Departments:

I. Division for Scientific Research.

Department 1. The Committee for the Founding of a Czechoslovak Ceramic Museum by the Czechoslovak Ceramic Society and the Czechoslovak Technical Museum in Prague.

Department 2. For List and Chart of Ceramic Raw Materials.

II. Division for Standardization.

Department 1, for Analyses of Portland Cement.
Department 2, for Refractory Materials.
Department 3, for Brick Products.
Department 4, for Floor Tile.
Department 5, for Wall Tile.
Department 6, for Stone Ware.
Department 7, for Taking of Standard Kaolin Samples.

III. School Division.

IV. Division for Economy of Heating.

V. Financial Division.

VI. Statistical Division.

Dr. Rudolf Barta

The president of this Society is elected for two years and committee members hold office for the same period. Frantisĕk Fischer, a pioneer of scientific ceramics in Czechoslovakia is president. The secretary is nominated by a committee and serves for two years. Rudolf Barta is now general secretary.

Other prominent ceramists of this country are Otaka Kallauner, head man of the Ceramic Institute and professor at the Technical State University in Brno; Karel Hineis, manager of the ceramic works in Rakovnik; Josef Burian, first professor of ceramic sciences at the Polytechnical State University in Prague; G. Kopka, manager of the Fuel Institute for Porcelain in Karlovy Vary; Fr. Kanhaüser, assistant to Dr. Kallauner in Brno; Josef Preller, assistant to Dr. Burian in Prague.

[1] Gen. Secy.

This Society issues a publication "Transactions" which contains English abstracts. The meetings held this year are as follows:

1. Prague, March 28, 1925.
   Lectures: (1) "Losses in the Brick Industry and the Possibility of Preventing Them," by A. Rezáč; (2) "Cement from Rotary and Shaft Kilns," by Josef Zitný; (3) "On Action of Scoring on Refractory Products," by Voclav Korber; (4) "On the Aceh Ceramic Terminology," by Josef Matejka.
2. Karlovy Vary, June 12 and 13, 1925.
   Lectures: (1) "The Tunnel Ovens in the Ceramic Industries," by V. Pohl; (2) "New Research in the Institute of Silicates in Brno," by O. Kallauner; (3) "Testing of Insulation," by J. Kopka.

MEETING OF AMERICAN REFRACTORIES INSTITUTE[1]

The meeting and the banquet of the American Refractories Institute will be held at the Waldorf-Astoria Hotel beginning at 10:00 A.M. October 29. The morning session will be opened with an address by W. C. Sproul, President, and then given over to a business meeting, reports of committees, etc. Following this a buffet luncheon will be served in a private dining room adjoining the room in which the meeting will be held. In the afternoon talks and papers will be given as follows:

"The American Refractories Institute," by J. D. Ramsay, Elk Fire Brick Co.; "Fire Brick Specifications," by J. Spotts McDowell, Harbison-Walker Refractories Co.; "Work of the Refractories Fellowship at Mellon Institute," by M. C. Booze; "Service Conditions in Boiler Furnaces," by Ralph A. Sherman, U. S. Bureau of Mines; "Shrinkage of Diaspore," by S. M. Phelps, Mellon Institute; "Organic Bonds for Silica Brick," by M. C. Booze, Mellon Institute.

A banquet, which is to be a stag affair, will be served at 7:00 in the evening. The speakers for this include Senator George Wharton Pepper, Elisha Lee, Vice-President of the Pennsylvania Railroad Company, and General T. Coleman du Pont. It is probable that Charles M. Schwab will also be present and talk on one of his favorite topics.

ST. LOUIS DISTRICT ENAMELERS' CLUB

Report of Meeting, September 29

Nineteen members were present at the meeting of the St. Louis District Enamelers' Club held on Sept. 29, at the American Annex Hotel, St. Louis.

W. V. Knowles of the Titanium Alloy Mfg. Company and member of the AMERICAN CERAMIC SOCIETY was a guest. Mr. Knowles gave a talk on various compounds and enameling. The chief address of the evening was presented by J. P. Wentworth of Beacon Factories, Inc., on "Your Value to Your Organization." Other speakers were J. P. Cole, J. B. Ford Company, who talked on "The Use of Cleaning Compounds," and Fred Janson, Wrought Iron Range Company, whose subject was "Ground Coat Burning on Steel."

[1] Advance announcement received Oct. 16, 1925. M. C. Booze, Acting Secretary.

EASTERN POTTERY MANUFACTURERS INVESTIGATE FELDSPAR PROPERTIES IN SOUTH[1]

The importance of the ceramic raw materials of the south is becoming more apparent every day. More and more of the northern and eastern pottery producers are investigating the various sources of feldspar, kaolin, ball and sagger clays and flint than ever before. This is especially true of the feldspar deposits.

Recently the following pottery manufacturers from the Trenton, New Jersey, district were guests of the Erwin Feldspar Company of Sprucepine, N. C., and Erwin, Tennessee, at which time a careful inspection of the mines and mills of the Erwin Company were made.

The party included Mr. and Mrs. Leslie Brown of Lenox Incorporated; Mr. and Mrs. J. M. Gilfillan of the Trumbull Electric Manufacturing Company; Andrew Foltz, President, Lambertville Pottery Company, Lambertville, New Jersey; John F. Hutchins, Manager, B. O. T. Manufacturing Company; Oscar Van Fleet, President, Van Pottery Company; Enoch Muntford, Manager, Anchor Pottery Company; George Martin, Manager, Keystone Pottery Company; C. H. Chamberlain, Manager, Bay Ridge Specialty Company; Prof. George H. Brown, Director of Ceramics, Rutgers University, New Brunswick, New Jersey; and Prof. A. V. Henry, Director of Ceramics, Georgia School of Technology, Atlanta, Georgia.

When the party arrived in Johnson City, Tennessee, from the east they left immediately in a special car attached to a regular train on the Clinchfield Railroad, for Sprucepine, N. C. Near Sprucepine the visitors were met by R. W. Lawson, President of the Erwin Feldspar Company and were taken to the mines on Crabtree Creek in a special car over the private railroad operated by the Erwin Company.

After making an inspection of the mines the party was taken to the hotel at Sprucepine at which place a banquet was tendered them. S. T. Henry of New York and Sprucepine extended a cordial welcome to the visitors and told them of the remarkable growth of western North Carolina and pointed out the many advantages of that section for industrial development. L. H. Phetteplace, General Manager of the Clinchfield Railroad reviewed in a most interesting way the industrial development in the territory traversed by the Clinchfield Railroad. Mr. Phetteplace predicts a much greater development during the next ten years and pointed out the advantages of this location for ceramic industries. Dr. Charles Peterson of Sprucepine, a local physician, told of the climatic advantages of western North Carolina and the desirability of this section from the standpoint of health. Mr. Smith, Manager of The Harris Clay Company, of Sprucepine, explained the method of mining and refining North Carolina kaolin.

On behalf of the guests, Leslie Brown, Andrew Foltz, George H. Brown and A. V. Henry responded in a most delightful manner. Mr. Brown told of his experiments with the use of North Carolina feldspar which have proven successful in the production of extremely high grade china. Messrs. Foltz and George H. Brown pointed out the necessity of keeping feldspar uniform and told in clear terms the requirements of the various manufacturers so far as feldspar is concerned. Prof. Henry reviewed his work at Georgia Tech. and explained in detail the ceramic raw materials of the southeast. He, too, predicted a rapid growth of the pottery and glass industry in the south. V. V. Kelsey, of the Erwin Feldspar Company, acted as toast master.

The visitors expressed surprise and interest in the great extent of the feldspar deposits in western North Carolina.

The following day the party made an inspection of the English Knob mines of the Erwin Company and returned to Erwin, Tennessee, where they visited the mills of the

[1] By V. V. Kelsey, Erwin, Tenn.

Company and were later guests of the Southern Potteries, Incorporated, of Erwin. They left for the east on Sunday night.

Prior to 1911 there was no feldspar being produced in North Carolina on a commercial scale. Today this territory is producing half the total amount of feldspar consumed by the various ceramic industries of this country. The industry has grown from a modest start in 1911 to its present size which argues well for the quality of this material from North Carolina.

During 1924 a total of 96,000 long tons of feldspar were mined in North Carolina which was more than the entire country consumed in 1921. This is a remarkable increase in three years. The production in 1924 represented an increase of 68% as compared with 1923.

CALENDAR OF CONVENTIONS

Organization	Date	Place
Amer. Assn. for Advancement of Science	Dec. 28–Jan. 2	Kansas City, Mo.
AMERICAN CERAMIC SOCIETY	Feb. 8–13, 1926	Atlanta, Ga.
American Chemical Society		
(Spring Meeting)	April 5–9, 1926	Tulsa, Okla.
American Concrete Institute	Feb. 23–26, 1926	Chicago, Ill.
Amer. Electrochemical Society	April 22–24, 1926	Chicago, Ill.
American Engineering Council	January, 1926	
American Face Brick Association	Dec. 1–3, 1925	Atlanta, Ga.
Amer. Institute of Chem. Engrs.	Dec. 2–5, 1925	Cincinnati, Ohio
Amer. Institute of Min. and Met. Engrs.	February 15, 1926	New York City
Amer. Iron and Steel Institute		
American Mining Congress		
(Annual Meeting)	Dec. 9–11, 1925	Washington, D. C.
(Western Division)	Nov. 16–19, 1925	Chandler, Ariz.
Amer. Soc. Mechanical Engrs.	Nov. 30–Dec. 3, 1925	New York City
Amer. Soc. Steel Treating	Jan. 21–22, 1926	Buffalo, N. Y.
Amer. Soc. Testing Materials	June 21–26, 1926	Atlantic City, N. J.
Amer. Zinc Institute	April 27–28, 1926	St. Louis, Mo.
Assn. Chemical Equipment Mfrs.	May 10–15, 1926	Cleveland, Ohio
Assn. Iron and Steel Mfrs.	May 31–June 5, 1926	Chicago, Ill.
Associated Tile Manufacturers	December 9, 1925	New York City
Baltimore-Washington Section		
(American Ceramic Society)	Dec. 5, 1925	Washington, D. C.
Coal Mining Institute of America	Dec. 9–11, 1925	Pittsburgh, Pa.
Common Brick Manufacturers	February 22–26, 1926	Atlanta, Ga.
Grinding Wheel Mfrs. of U. S. and Canada	Dec. 11, 1925	Buffalo, N. Y.
Hollow Building Tile Assn.	January, 1926	Chicago, Ill.
Manufacturing Chemists' Association	May or June, 1926	Near New York City
Natl. Acad. of Sciences	Nov. 9–11, 1925	Madison, Wis.
(Spring Meeting)	April 26–28, 1926	Washington, D. C.
Natl. Assn. of Mfrs. of Pressed and Blown Glassware	March 9, 1926	Pittsburgh, Pa.
Natl. Assn. Stove Mfrs.	May 12–13, 1926	New York City
Natl. Brick Mfrs. Assn.	Nov. 2–7, 1925	St. Louis, Mo.

Organization	Date	Place
Natl. Exposition of Coal Mining Mach.	Dec. 2–5, 1925	Cincinnati, Ohio
Natl. Exposition of Power and Mechanical Engrs.	Nov. 30–Dec. 5, 1925	New York City
Natl. Glass Distributors Assn.	Nov. 10–11, 1925	New York City
Natl. Paving Brick Mfrs. Assn.	January, 1926	
Natl. Society Vocational Education	Dec. 3–5, 1925	Cleveland, Ohio
Natl. Terra Cotta Society	Nov. 13–14, 1925	Washington, D. C.
Natural Gas Assn. of America	May 17–20, 1926	Tulsa, Okla.
New Jersey Clayworkers' Assn.	Dec. 18, 1925	New Brunswick, N. J.
Ohio Ceramic Industries Assn.	Nov. 20–21, 1925	Columbus, Ohio
Sand-Lime Brick Assn.	Feb. 9–15, 1926	New Orleans, La.
Taylor Society	Dec. 3–5, 1925 1925	New York City

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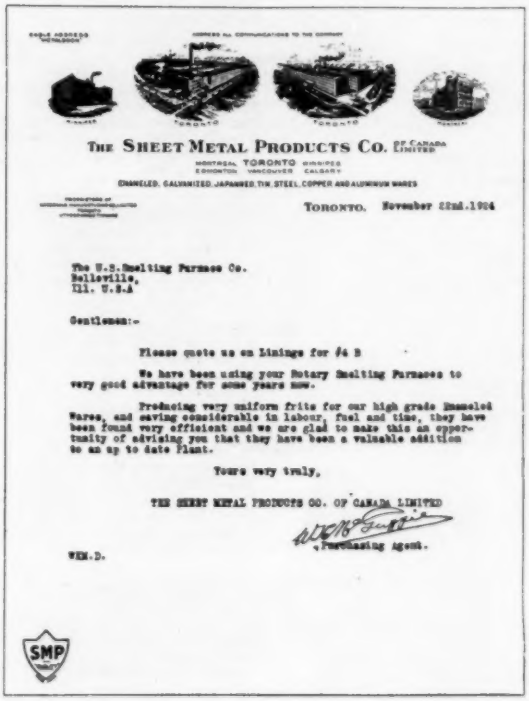

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Chambers Brothers Co.

Bricks (Refractory-Alundum-Crystolon)
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C

Cars (Clay)
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Carbonates (Barium-Lead)
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Norton Co.
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Clay (China)
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Clay (Electrical—Porcelain)
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Harshaw, Fuller & Goodwin Co.
Paper Makers Importing Co., (Inc.)
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay (Enamel)
Edgar Brothers Co.
Paper Makers Importing Co.
Metal & Thermit Corp.
United Clay Mines Corp.
Vitro Mfg. Co.

Clay (Fire)
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Paper Makers Importing Co., (Inc.)
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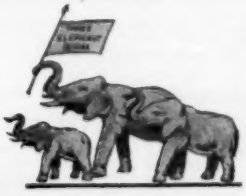

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D

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Dryers (Steam Pipe Rack)
Lancaster Iron Works, Inc.

Drying Machinery
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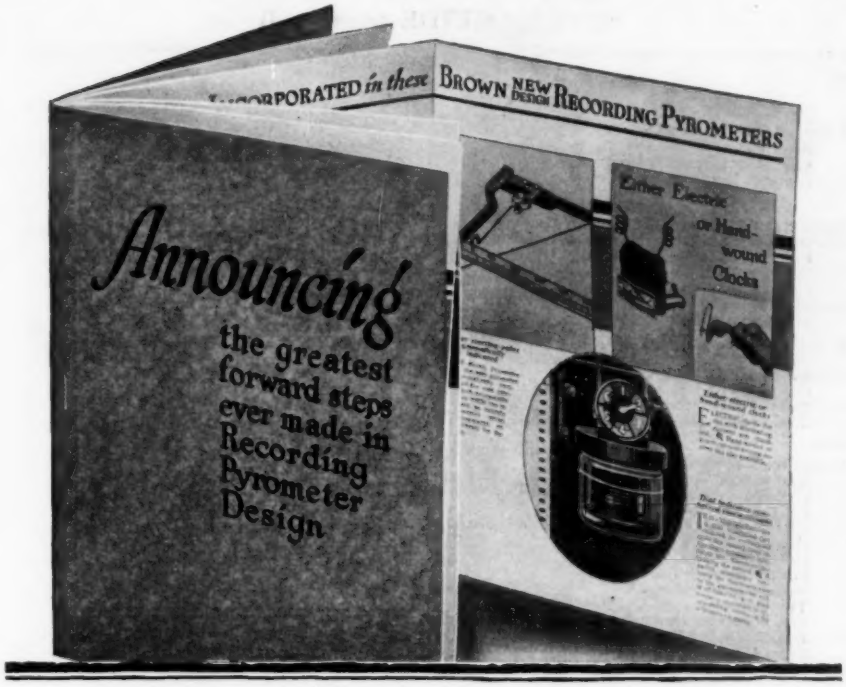
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Vitro Mfg. Co.

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Enameling Muffles
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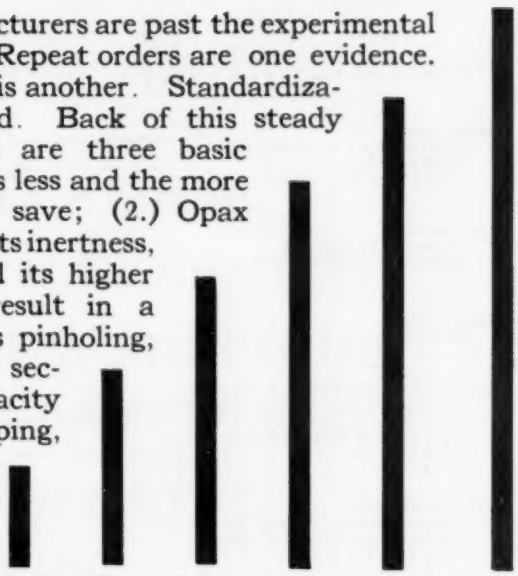

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From a single inactive mine in this county about 12 years ago, there has been developed in Wilkinson County a prosperous group of clay mines, refineries, and brick plants, whose products are being shipped in large quantities to all parts of the country. The crude and refined clays are used in the manufacture of tile, porcelain, whiteware, pottery, sanitary ware, refractories, paper rubber, textiles, etcetera. The county lies wholly within the Coastal Plain, and the clays are mostly of the Lower Cretaceous, which are the most dependable in character and thickness.

The county is almost evenly divided by Commissioner Creek which flows in an easterly direction and is fed by numerous smaller streams from both the north and south.

Commissioner Creek is on the 240 contour about sea level. The ridges flanking the creek on both sides rise to an altitude of 300 to 350 feet with knolls or peaks above 400 feet. This area is cut at intervals by the lateral tributaries flowing from the ridges.

The mines and commercial outcrops are uniformly on about the 300 foot contour. The overburden consists of sand, red, and refractory clays, and sometimes fuller's earth, and varies from 5 to 20 feet. The main line of the Central of Georgia Railway follows the valley of Commissioner Creek and being below the level of the clay deposits, plants may be located at the railroad and the clay brought to them by tram or industrial roads with the advantages of having the grade with the loaded cars.

The rolling topography of the county affords easy mine drainage and simplifies the disposition of overburden, while the numerous streams afford ample water for refining and other plant purposes.

Yet, Wilkinson County is only one of fifteen counties in the great clay belt of Georgia through which the Central of Georgia Railway operates. The vast deposits in this region cover about 10,000 square miles and are the most extensive in Eastern United States. They are mainly surface deposits and easy to mine at low cost.

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Directory of Commercial Minerals in Georgia and Alabama along Central of Georgia Railway.

The Utilization of Georgia Clays for Refractories.

Use of Sedimentary Kaolins of Georgia in Whitewares.

Kaolin and Refractory Clay Deposits in Wilkinson Co., Ga.

Washing Tests of Georgia Clays.

Georgia Clays for Paper Fillers.

Georgia Clays for Rubber Filler.

Utilization of Georgia Kaolins in the manufacture of Face Brick.

Distribution of Kaolin and Bauxite of the Coastal Plain of Georgia.

American Ceramic Society Annual Convention, Atlanta, February 8-13th, 1926.

Central of Georgia Railway

J. M. MALLORY
General Industrial Agt.

CENTRAL OF GEORGIA

233 West Broad Street
Savannah, Ga.

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W

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Z

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	Page
American Rolling Mill Co.	11
American Trona Corp.	7
Best, W. N. Corp.	26
Brown Instrument Co.	9
Carborundum Co.	32
Caulkins & Co., H. J.	20
Central of Georgia Railway	17
Chambers Brothers Co.	24
Chicago Vitreous Enamel Product Co.	7
Drakenfeld and Co., B. F., Inc.	15
Edgar Plastic Kaolin Co.	25
Engelhard, Charles, Inc.	27
Eureka Flint & Spar Co.	3
Ferro Enamel Supply Co.	25
General Electric Co.	35
Hadfield-Penfield Steel Co.	27
Harshaw, Fuller and Goodwin Co.	2
Holcroft & Co.	23
Hy-Grade Manganese Co., Inc.	23
Innis, Speiden & Co., Inc.	26
Journal of the Society of Glass Technology	21
Lancaster Iron Works, Inc.	30
Lapp Insulator Co.	23
Leeds & Northrup Co.	1
Mansfield Sheet & Tin Plate Co.	30
McDanel Refractory Porcelain Co.	23
Metal & Thermit Corp.	Outside Back Cover
Montgomery Porcelain Products Co.	24
Mueller Machine Co., (Inc.)	20
National Silica Co.	31
Newark Wire Cloth Co.	7
Norton Co.	34
Paper Makers Importing Co. (Inc.)	33
Parker Russell Co.	23
Pennsylvania Pulverizing Co.	26
Pennsylvania Salt Mfg. Co.	18
Philadelphia Drying Machinery Co.	36
Porcelain Enamel & Mfg. Co.	Inside Back Cover
Potters Supply Company	31
Proctor and Schwartz, Inc.	4
Professional Directory	28
Roessler and Hasslacher Chemical Co.	Inside Front Cover
Seaboard Fuel Corporation	22
Spinks Clay Co., H. C.	18
Titanium Alloy Mfg. Co.	13
United Alloy Steel Corp.	29
United Clay Mines Corp.	23
U. S. Smelting Furnace Co.	5
Vitro Manufacturing Co.	25
Watson-Stillman Co.	24

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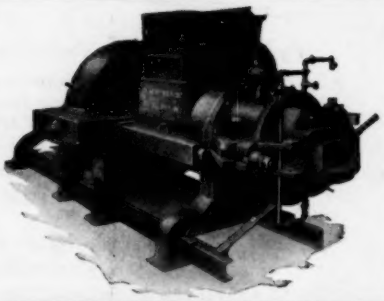

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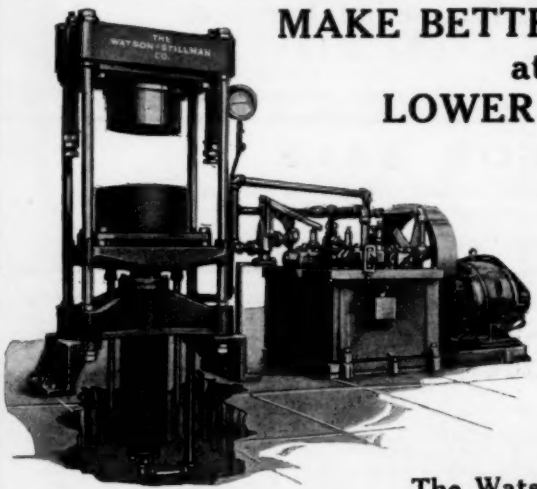

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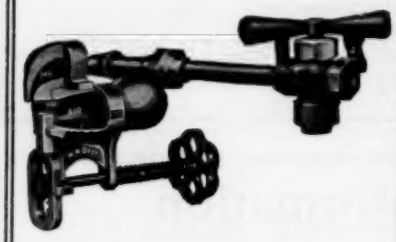

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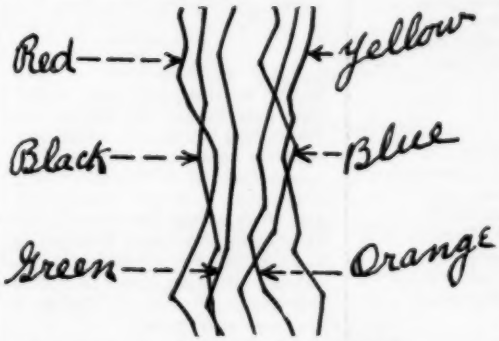

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The Mansfield Vitreous Enameling Company of Mansfield, Ohio, are enlarging their plant, adding two large Alundum furnaces, with double fork and Unloaders, Automatic Dryers, etc. Equipment is being installed by The Ferro Enamel Supply Company of Cleveland, Ohio.

Bill McGill, formerly with the Richardson & Boynton Company of Dover, New Jersey, and later with the Buckwalter Stove Company of Royersford, Pennsylvania, is now managing the Enameling Department of the Standard Gas & Equipment Company of Baltimore.

Mr. Harry Goudy, formerly with the Standard Gas & Equipment Company of Baltimore, is now connected with the Porcelain Enamel & Mfg. Company of Baltimore.

CERAMIC BREVITIES

THE Buck's Stove & Range Company of St. Louis recently relined one of their enameling furnaces with a Norton Alundum Muffle. The Karr Range Co. of Belleville, Illinois is also installing an Alundum Muffle.

The Ferro Enamel Supply Company of Cleveland, Ohio, is installing two large Alundum enameling furnaces for the National Stove Company, Lorain, Ohio.

The Wolverine Porcelain Enameling Company of Detroit, Michigan, which is being operated under the direction of PEMCO, is planning still further increase in their plant and next month a 60 x 160 inch furnace will be installed by the Porcelain Enamel & Manufacturing Company. They are also installing two more PEMCO Double Forks.

After a shut-down of two weeks, to re-arrange and install new equipment, the Cincinnati Enameling Company, which was recently taken over by the Porcelain Enamel & Manufacturing Company, started operations last week, under the name of the Buckeye Porcelain Enameling Company. Mr. James Gould, former manager of PEMCO'S Scranton plant, has full charge of this new enterprise.

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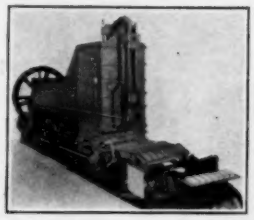

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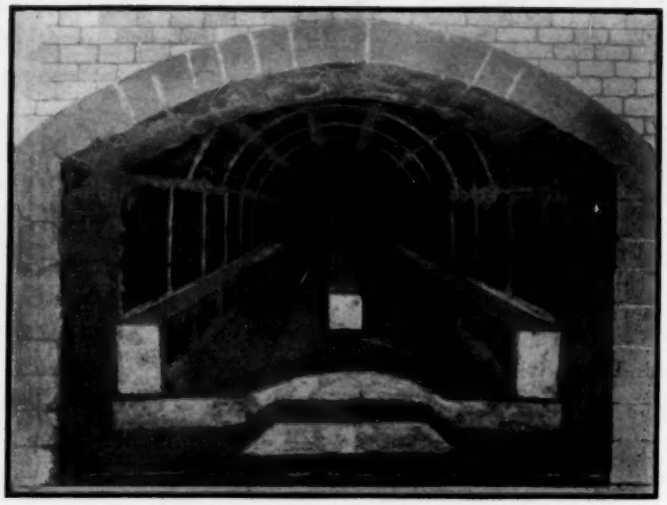

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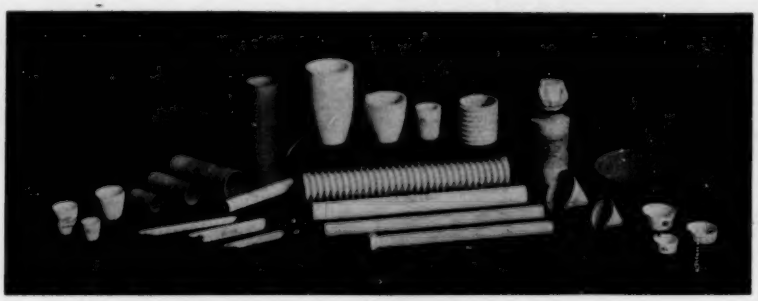

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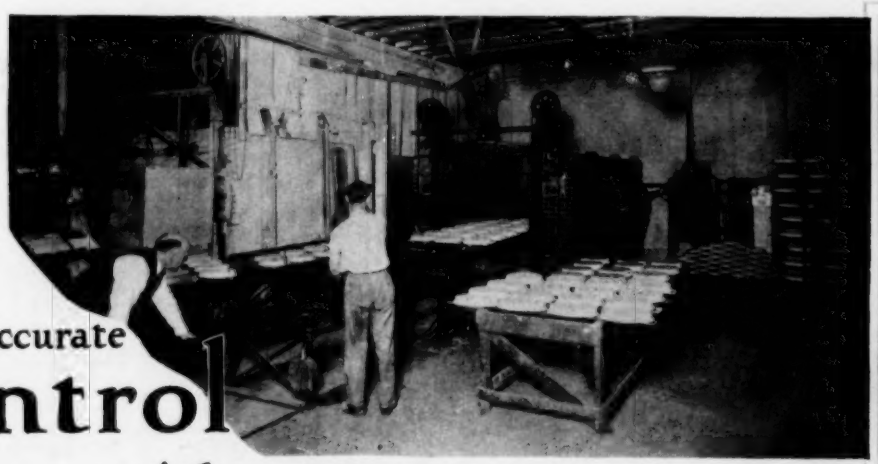

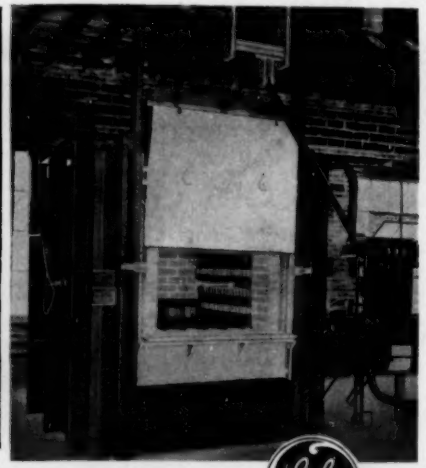

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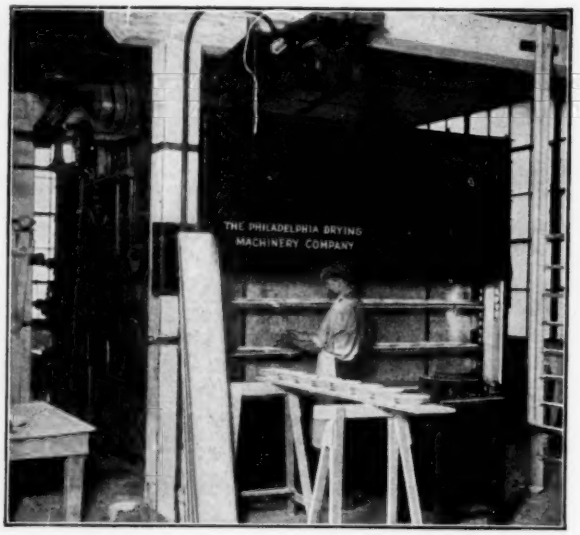

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